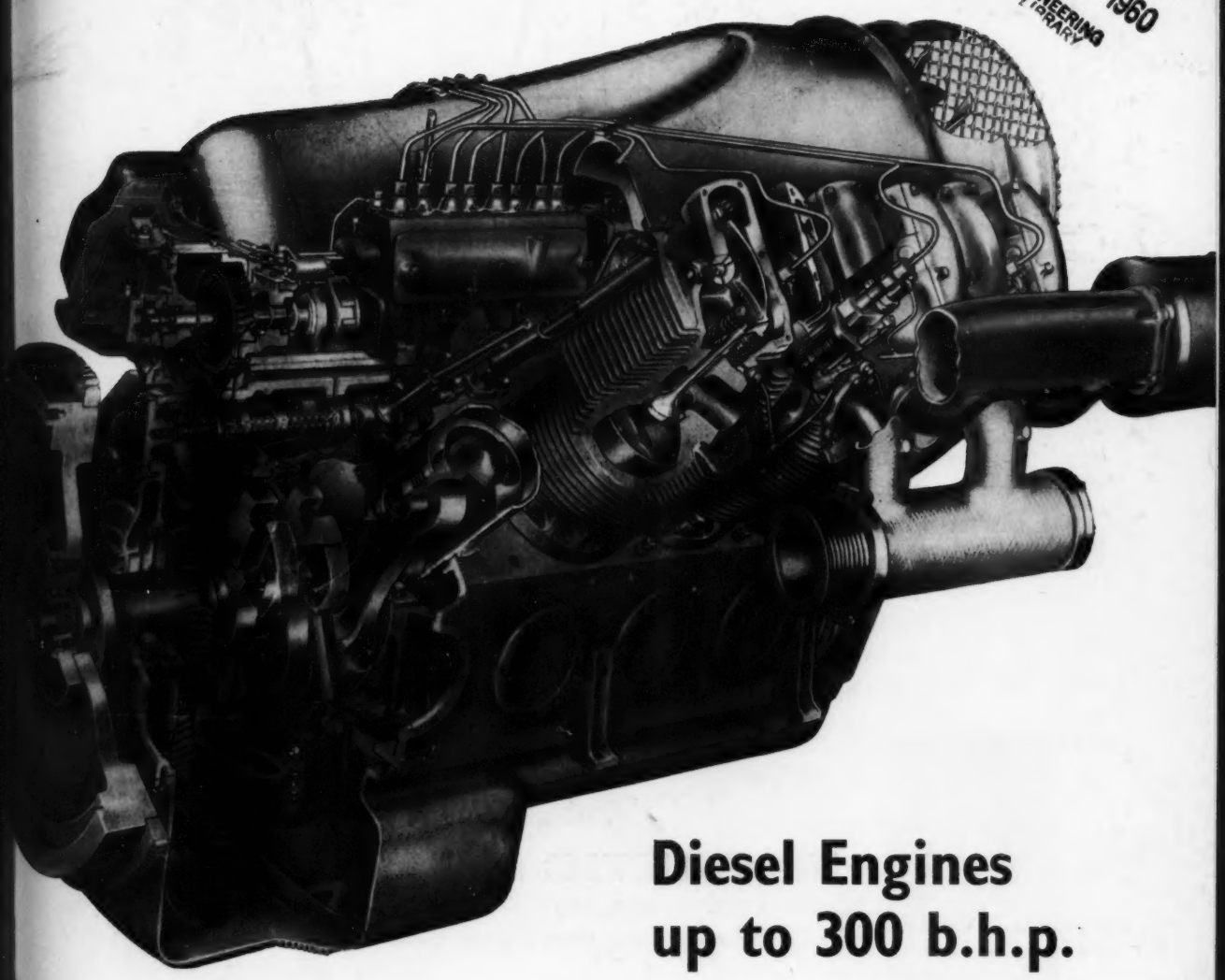
& Use of Materials, Components & Finishes in Engineering Design

ngineering Materials and Design

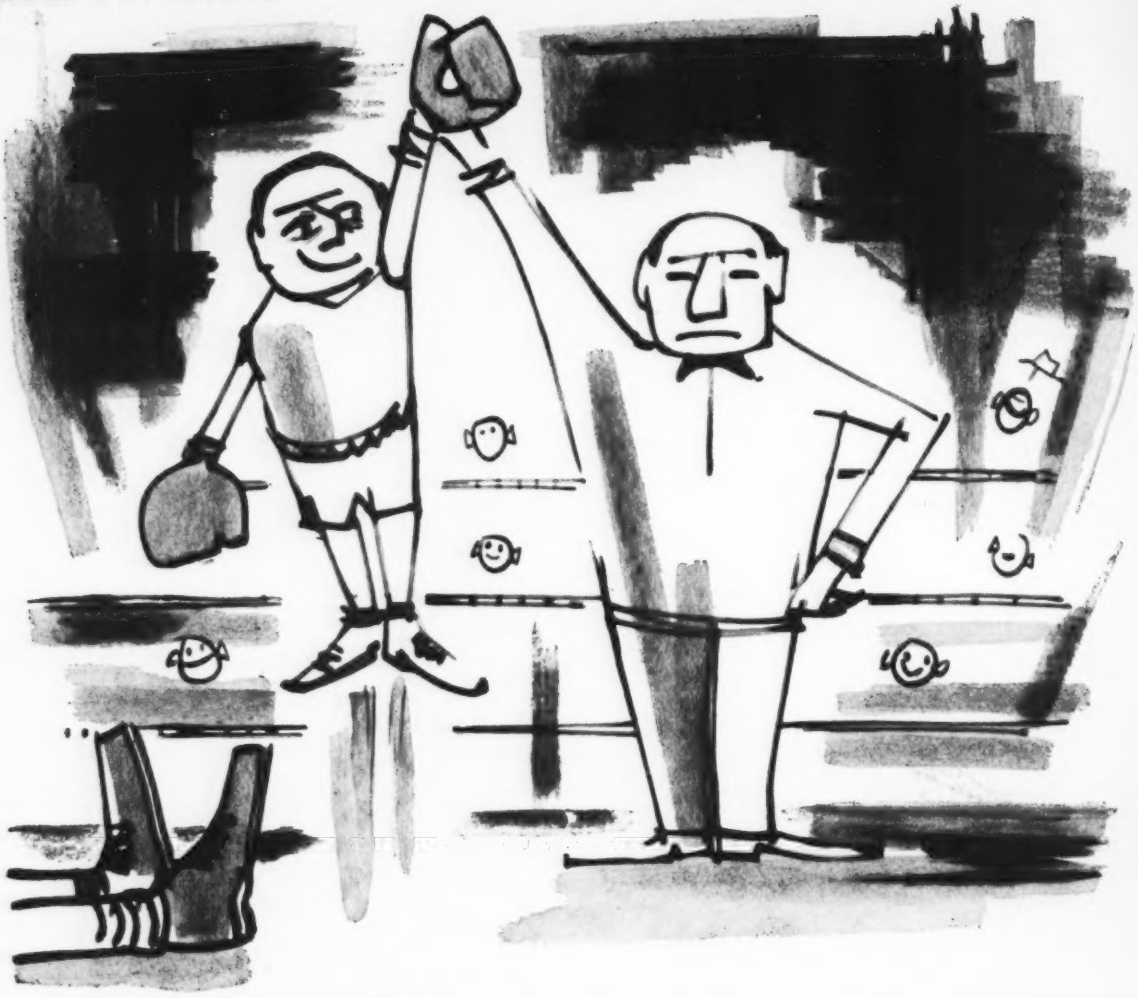
UNIVERSITY OF MICHIGAN
NOV 15 1960
ENGINEERING LIBRARY



Diesel Engines up to 300 b.h.p.

page 688

EMD 3887 for further information



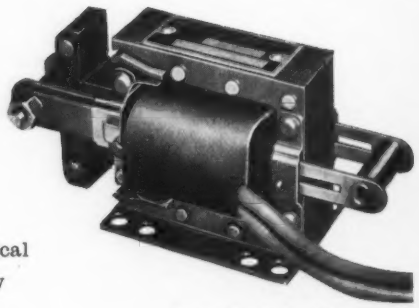
Smaller Size - Higher Power

Magnetic Devices produce a wide range of solenoids with exceptionally high force/size ratios.

★ **COMPACT** ★ **ROBUST** ★ **AVAILABLE FOR PUSH OR PULL DUTIES**

To ensure maximum efficiency with greatest economy there is much more to solenoids than just a simple 'push' or 'pull'.

We have had considerable experience in Solenoid applications. Our specialist knowledge and technical service are at your disposal — let us show how solenoids can solve *your* problem.



Series 574 Solenoid

MAGNETIC DEVICES LIMITED

AID & ARB APPROVED

MAGNETIC DEVICES LTD

NEWMARKET · ENGLAND

Tel: Newmarket 3181 (5 lines) Grams: Magnetic Newmarket

P 4537

Engineering Materials and Design

★ *The Magazine for Engineering Designers*

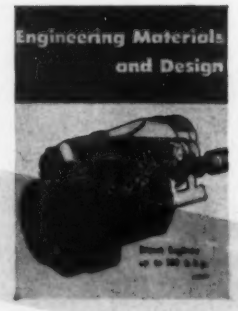
A HEYWOOD PUBLICATION

Vol. 3 No. 11 November 1960

EDITOR
H. R. Heap, B.Sc., A.M.I.E.E.

TECHNICAL EDITOR
R. D. Cullum, M.I.E.D., A.R.Ae.S., M.I.A.S.

ASSISTANT EDITORS
F. R. Terrell
J. B. Howson



COVER: One of the range of Vega air-cooled diesel engines made by Davey, Paxman & Co. Ltd. The one shown is an eight-cylinder direct injection engine of V form construction. The range is available either normally aspirated or in the pressure-charged form.

Published monthly by HEYWOOD & COMPANY LTD., Drury House, Russell Street, London, W.C.2 (Tel.: TEMple Bar 3422), on the 15th of the preceding month. Annual subscription 35s. sterling per annum ($5.25, U.S.A. and Canada) throughout the world. Single copies to order from all newsagents and bookstalls, 2s. 6d. each (by post from the publishers, 3s. 0d. each). BRANCH OFFICES: Royal Buildings, 2 Mosley Street, Manchester, 2, Tel.: Central 9935; Bayliss House, Hurst Street, Birmingham, Tel.: Midland 5786; 52 St. Enoch Square, Glasgow, Tel.: City 3492; 527 Madison Avenue, New York, 22, N.Y., Tel.: Plaza 9-1171.

© Heywood & Company Ltd., 1960. Must not be reproduced without written permission.

ISSUE AT A GLANCE

page

PROPERTIES OF RUBBER **676**
Mechanical, static and dynamic properties; and design of components.
By **D. F. Aitken.**

EFFECT OF NEUTRON IRRADIATION ON THE TRANSITION TEMPERATURE OF STRUCTURAL STEELS **681**
Brittle fracture characteristics, and other mechanical properties.
By **N. L. Parr**, F.I.M., A.M.I.Mech.E.

DIESEL ENGINES UP TO 300 B.H.P. **688**
Design features and tabulated data.

RUSSIAN TECHNICAL TRANSLATIONS **698**
Survey of those journals currently available in English.
By **H. L. R. Hinkley.**

OTHER FEATURES

Noise Causes Fatigue in Metals **680**

Novel Equipment at Farnborough **684**

Designer's Notebook **685**

New Ideas in Design **702**

Russia Revisited **704**

Glass Ceramics for Ball Races **705**

Galvanic Corrosion: Data Sheet **715**

Bursting Strengths of Tubes and Cylinders: Data Sheet **717**

REGULAR FEATURES

Materials in the News ... **665**

Editorial **675**

Overseas Newsletter **707**

New Books **708**

Letters to the Editor **713**

New Materials **721**

New Components **723**

New Equipment **727**

New Publications **727**

News of Industry **729**

CLASSIFIED ADVERTISEMENTS ... ... facing page **672**

Résumés

PROPRIETES DU CAOUTCHOUC

par D. F. Aitken page 676

L'article énumère les propriétés mécaniques, statiques et dynamiques des divers types de caoutchouc et étudie les problèmes de la fabrication des pièces en caoutchouc.

EFFETS DE L'IRRADIATION SUR LES ACIERS DE CONSTRUCTION

par N. L. Parr page 681

L'auteur étudie les effets de l'irradiation neutronique sur les caractéristiques mécaniques, en particulier la résistance à la fracture, des aciers utilisés dans la construction des réacteurs nucléaires. Les résultats des travaux partiellement achevés montrent qu'une partie importante de la ductilité du métal se perd sous l'influence combinée de la radiation et de la chaleur.

TRADUCTIONS DE PUBLICATIONS TECHNIQUES RUSSES

page 698

Revue des publications russes que l'on peut obtenir, en ce moment, en Anglais, avec les nom et adresse des éditeurs, les prix et une indication de l'étendue de la traduction (traduction résumée ou in extenso).

LES MOTEURS DIESEL JUSQU'A 300 CV

page 688

Revue complète donnant les caractéristiques de construction et les données numériques, sous forme de tables, des moteurs Diesel fabriqués dans le Royaume-Uni.

Kurzreferate

DIE EIGENSCHAFTEN VON GUMMI

von D. F. Aitken Seite 676

Der Artikel bespricht die mechanischen, statischen und dynamischen Eigenschaften verschiedener Gummiarten und befasst sich mit Problemen der Zusammenstellung von Gummikomponenten.

BESTRAHLUNG VON BAUSTÄHLEN

von N. L. Parr Seite 681

Die Wirkung der Neutronenbestrahlung auf den Sprödigkeitsbruch und andere mechanische Eigenschaften von Stählen, die beim Bau von Atomreaktoren benützt werden, werden näher untersucht. Ergebnisse eines teilweise durchgeführten Arbeitsprogramms zeigen, dass ein grosser Teil der Zähigkeit durch eine Kombination von Strahlung und Temperatur verloren geht.

ÜBERSETZUNGEN RUSSISCHER TECHNISCHER ZEITSCHRIFTEN

Seite 698

Eine Übersicht der gegenwärtig in englischer Sprache erhältlichen Zeitschriften mit Namen und Anschriften der Herausgeber und Angabe über Preis und ob die Übersetzung im Auszug oder vollständig ist.

DIESELMOTOREN BIS ZU 300 BREMS-PS

Seite 688

Eine umfassende Übersicht mit Konstruktionsdaten und Tabellen der in Grossbritannien hergestellten Dieselmotoren.

Резюме

СВОЙСТВА РЕЗИНЫ

Д. Ф. Айткен стр. 676

В статье излагаются механические, статические и динамические свойства различных сортов резины и обсуждаются проблемы, связанные с конструированием резиновых деталей.

ВЛИЯНИЕ ИЗЛУЧЕНИЙ НА КОНСТРУКЦИОННУЮ СТАЛЬ

Н. Л. Парр стр. 681

Были изучены проблемы влияния нейтронных излучений на хрупкую ломкость и другие механические свойства сталей, идущих на постройку ядерных реакторов. Результаты частично завершенной программы свидетельствуют об утрате значительной степени вязкости под совместным воздействием излучений и высоких температур.

ПЕРЕВОДЫ РУССКИХ ТЕХНИЧЕСКИХ ЖУРНАЛОВ

стр. 698

Обзор тех журналов, которые в настоящее время переиздаются на английском языке, с указанием издательств и их адресов, характера перевода (резюме или полный текст) и цены.

ДИЗЕЛЬНЫЕ ДВИГАТЕЛИ МОЩНОСТЬЮ ДО 300 *л.с.*

стр. 688

Исчерпывающий обзор, в котором приведены конструкционные особенности и информационные таблицы, касающиеся дизельных двигателей, производимых в Великобритании.

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Direct Conversion—Research at C.E.G.B.

THE CENTRAL ELECTRICITY GENERATING BOARD'S research and development department is about to engage on a long-term programme of research into various methods of direct conversion of fuel energy into electricity. The experimental work is being done by the advanced projects division of applications branch, in laboratories situated at Croydon Power Station. The methods under examination include fuel cells, thermionic and thermoelectric conversion, and direct generation by passing hot conducting gases through a magnetic field using a concept sometimes known as magnetohydrodynamics (M.H.D.). In all cases the object is to examine more direct methods for generation than those now employed, in the hope that reduced capital costs, and higher efficiencies, may be achieved.

The work on fuel cells is aimed first at establishing whether a reversible fuel cell (probably of the hydrogen-oxygen type) can be used economically for large-scale storage of electricity —in competition with, say, pumped-water storage. To this end the experimental work is being supported by engineering and economic studies of large systems. A second, and ultimately more important aim, is to establish whether a fuel cell (probably of the high-temperature carbonate-electrolyte type) could be used for primary generation, using a relatively cheap gas obtained by gasification of coal or oil. There are many difficult problems of materials and fabrication techniques, as well as fundamental problems concerning the performance and life of electrodes, which have to be solved before fuel cells can be seriously considered for large-scale generation. Further, should these problems be solved, it will be necessary to demonstrate that fuel cells can be made which will compete successfully with modern high-performance low-cost sets, and that they have operational features which commend them to the operational needs of the industry.

The other methods of direct conversion are probably less well developed than fuel cells, and the object of the initial work is largely to study the basic science of such devices, since there are many physical, as well as engineering, unknowns. These methods seem however to be well worth further study, since they offer the prospect of attaining appreciably higher useful upper temperatures in the thermodynamic cycle than are attained by present or foreseeable steam plant. In order of advancing temperature, it is possible that thermoelectric, thermionic and M.H.D. generation devices may find a place singly, or perhaps in cascade, to provide thermodynamic "topping". By this is meant that, after energy has been extracted from combustion gases (or gas heated in a nuclear reactor) directly in the form of electricity, the cooler gases are passed to a boiler or gas turbine to generate further electricity in a more conventional manner. It must be emphasised that here again there are many materials problems to be solved, in addition to the scientific problems, before these devices can be considered for supplementing or replacing conventional plant.

Television for Internal Welding

SULZER BROTHERS, of Switzerland, have ordered from Quasi-Arc Ltd. a complete automatic welding installation for the fabrication of "pen-stock" pipes. These pipes are used for water conveyance in hydro-electric schemes, and vary between 16 in. and 8 ft. in diameter.

The automatic welding installation will produce all the internal and external longitudinal and circumferential seams, in pipe sections up to 13 ft. long, weighing up to 6 tons. It consists of three main units: a fixed internal welding boom; a fixed cantilever for external welding; and a mounted traversing roller bed for supporting the pipe lengths.

A special feature of the equipment is the use of a closed circuit television system for observation of the welding process when welding internally on small-diameter pipes. The television camera is mounted on the end of the boom, and remote adjustment is provided to ensure that it is always focused on the point of weld. The picture of the weld is shown on a television monitor screen on the control console, and the progress of the welding operation can thus be followed by the operator, who is also able to see that the welding nozzle is following the line of the seam.

The internal welding boom can be raised and lowered electrically to suit different diameter pipes, and it carries two welding heads arranged for the Unionmelt multi-power submerged arc process. The boom also carries the hopper for the flux powder, as well as the television camera and necessary floodlighting equipment. The welding heads may alternatively be arranged for Unionmelt parallel electrode welding, or for gas shielded welding using a single bare wire electrode.

The cantilever welding machine carries two similar heads arranged for multi-power welding of external seams. A platform mounted on the cantilever provides the operator with good access to the point of weld and to the control panel on the cantilever arm. The vertical column is a rigid box section provided with machined slideways to ensure smooth motion of the cantilever arm. The a.c. power supply equipment for each machine consists of two 1,000-amp. Scott-connected transformers with associated power factor correction capacitors and contactor cubicles.

The roller bed installation comprises one drive bed and one idler bed, the drive bed providing both high-speed positioning and a wide range of welding speeds for rotation and longitudinal traverse. Control of the roller beds is provided both at the remote control console and at the end of the cantilever arm, enabling a single operator to perform either operation. A further control station is provided by means of remote control boxes, which may be fitted at the end of the internal welding boom when the pipe diameters are large enough to allow the operator to enter. Unfused flux powder is recovered by means of vacuum units built into both welding machines.

Sulzer Brothers Ltd. are the oldest and largest firm in Switzerland manufacturing strakes for pen-stock pipes and pressure vessels. The firm is also noted for being one of the world's most important builders of large diesel engines, and takes a leading part in the manufacture of turbines, pumps and compressors.

New Journal on Cryogenics

AN INTERESTING JOURNAL devoted to low-temperature engineering and research has just been published. Until recently this subject was limited to gas liquefaction and rectification, but it is now expanding into many fields of light and heavy engineering. The increasing use of liquid gases in industry and the current interest in the properties of materials at very low temperatures has been responsible for great research activity on this subject. Articles in the first issue of Cryogenics include: "Metallography at Liquid Helium Temperatures", by Dr. D. Hull and Dr. H. M. Rosenburg; "Recent Improvements in Insulants", by A. H. Cockett and W. Molnar; "The Effect of Radiation Damage on the Thermal Conductivity of Superconductors", by K. D. Chaudhuri, Dr. K. Mendelssohn, F.R.S. and M. W. Thompson, A.E.R.E.; and "On the Properties of the Vapour Pressure Curve", by E. H. Brown.

RIDING MOWER

The riding mower shown on the right has been introduced by the Porter-Cable Machine Co., of New York. The wheels, cutter, blade and steering bar are attached to an aluminium chassis. The corrosion resistant glass-fibre body is elegantly designed.

REINFORCED PLASTICS CATAMARAN

Canada's first glass-fibre reinforced plastics catamaran in action at moderate speed. Named the "Tigercat," this 22-ft. express cruiser has been developed by Aero Marine Industries, of Ontario.

PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN

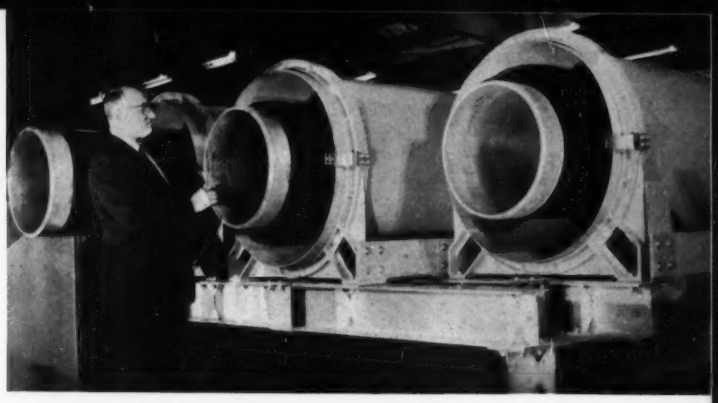
ENGINEERING MATERIALS IN PHOTOGRAPHIC EXHIBITION

Walter Nurnberg, the British industrial photographer, staged a one-man show of his pictures of British industry in action as part of an exhibition of the world's best photographs, held in Cologne recently. This picture (below) from his display is entitled "Storekeeper," and was photographed for the Imperial Typewriter Co. Ltd., of Leicester.

DIFFERENTIALLY HEATED GRAPHITE ASSEMBLY

In the picture below an operator is shown adjusting end heaters to a differentially heated graphite assembly, at the Atomic Energy Establishment, Winfrith, Dorset. This assembly is part of research into local temperature variations which occur within the lattice of an operating power reactor.

HAMMOTH ALUMINIUM BUSBARS
An engineer of the Delta Star Electric Division, H. K. Porter Co., examines 19-in. dia. aluminium tube conductors produced by Aluminium Co. of America on a 14,000-ton extrusion press. These busbars are for service at 10,000-11,500 amp., 12.6 to 16.5 kV.



LONG-DISTANCE WAVEGUIDES
Research on the transmission of very high frequencies along circular waveguides may lead to considerable cost savings on long-distance telephone circuits. On the left, measurements are being made to determine the effectiveness of a component such as would be used to connect together hollow tubes of different diameters.

PLASTICS ENVELOPE FOR SEACAT
A weatherproof glass-fibre travelling canister is placed over a Short Seacat missile. The missile is already sealed inside its protective plastic envelope and mounted on the canister base. Envelope and canister together will give the Seacat complete protection against tropical humidity and extremes of temperature.

POLYETHYLENE CHROFFLES
Layer of ball chroffles blanketing the surface of a large chrome bath used for chromium facing electros, and original printing plates, at the works of Hazell Watson and Viney, printers, of Aylesbury. The chroffles are blow-moulded by Lacrinoid Products Ltd. and sold by W. Canning and Co. Ltd.

E.M.D. 3986 for further information

DESIGNERS OF CLUTCH AND POWER TRANSMISSIONS

see Ferodo First for sintered metal & cermet friction linings

when duties beyond the scope of conventional friction materials are called for

FERODO FIRST
FOR LIGHT
AND HEAVY DUTY

FERODO

FERODO LIMITED · CHAPEL-EN-LE-FRITH
A Member of the Turner & Newall Organisation

9/10

Sandwich Panels

WELL TO THE FORE at the Farnborough Air Show was a material which is finding many new uses where the combined virtues of light weight and high strength are a prime design requirement. Manufactured by William Mallinson & Sons Ltd., a number of types under the general family name of Mallite EGB are now available.

Standard panels have cores of end grain balsa wood (grain running perpendicular to the panel face), to each side of which are bonded either light alloy or Durestos sheets. Durestos is a resin impregnated asbestos felt having a tensile strength of 30,000 p.s.i., while the L72 aluminium alloy used as the alternative has a tensile value of 53,760 p.s.i. The balsa core strength is 1,400 compressive and 3,000 p.s.i. tensile. Panels may be further strengthened by the addition to the core of equally spaced hardwood strips. One such type is Mallite EGB 2, a standard panel having $\frac{1}{2}$ in. wide birch strips at 3 in. centres bonded into the core.

Many strength tests have been carried out in support of the company's programme of aircraft flooring installation, which is the main outlet for the material in the aircraft industry. Typical of the results obtained are the following: (a) Mallite EGB 4 type 26/26a 1/4 ($\frac{1}{4}$ in. thick balsa core faced both sides with 26 s.w.g. L72)—impact up to 100 ft./lb., and indentation loads on a 10-mm. ball up to 700 lb. (both before local skin fracture occurred); (b) Mallite EGB 2 type 26/26a 5/8 ($\frac{5}{8}$ in. thick balsa core, $\frac{1}{2}$ in. birch strips, faced both sides with 26 s.w.g. L72)—proof loaded to 1,800 lb./sq. ft.

Moisture absorption of the balsa core is very low, and temperature effects small. Thus the material is stable, and gives a constant strength over a temperature range of −40 to +50 deg. C.

The panels are supplied with various core and facing thicknesses to suit the strength requirements of the design. They may be had faced with differing gauges of plate or Durestos on each side, and additionally with any of the decorative plastics finishes bonded to one or both faces. In use the material should be treated much the same as plywood or other similar sheet products. It may be sawn, routered or spindled, provided cutting edges appropriate to the facing materials are used. Where load carrying attachments are made, distance tubes the full thickness of the panel should be used. It is possible to blind-rivet lightly loaded members to one skin only, leaving the other skin, which may be in view, untouched. Hardwood, plastics or extruded edgings may be set in using normal woodworking techniques and adhesives.

Replacement floors are now being supplied for a number of types of aircraft, including Viscounts, Vikings, Dakotas and Doves. Air Registration Board approval has been obtained for the use of Mallite in these modifications. So successful have been the results of these installations that the material is now being specified during the initial design stage for either flooring or bulkheads in several new aircraft. Although most of the other equipment already developed from the material (aircraft galley units, meal boxes, etc.) is of immediate interest only to the aviation industry, it would appear that the panels have applications in more everyday structural design.

Electric Wrist Watch

ALTHOUGH ELECTRIC WATCHES are not really new — the Hamilton electric watch, made by Ingersoll Ltd., and described as the world's first electric watch, has been fully proved by sales running into many thousands over the past four years in the U.S.A.—none of these watches have previously been imported for general sale in Britain.

In this watch, the platinum-cobalt magnet motor is powered by a tiny energy cell the size of a shirt button, which releases its power in such a miserly fashion that it opens and closes the electric circuit of the watch 75,000,000 times in a year. The energy cell is guaranteed to run the watch for over a year.

Stainless Steel Engine

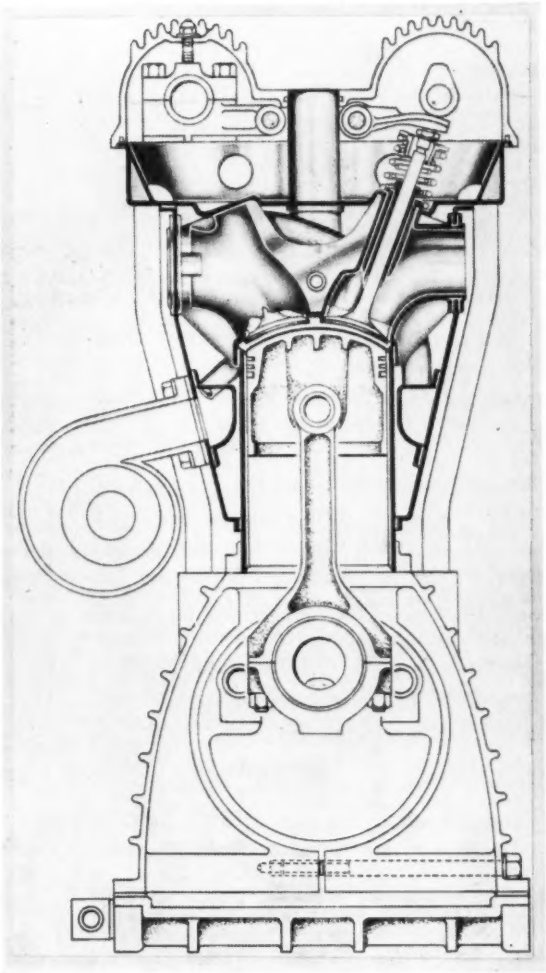
A REMARKABLE NEW FOUR-CYLINDER ENGINE, featuring a block assembly of welded and brazed thin gauge type 302 stainless steel sheet, is nearing full-scale production at Tyce Engineering Corp. It utilises recent advances in brazing techniques to ensure a lightweight, powerful and durable engine.

Combining lightness and power, the dual overhead cam engine, which is available in four displacements, develops up to 1 h.p./lb. and more than 1 h.p./cu. in. Scheduled to be installed first in sports cars, racing cars and boats to prove its potential under competition conditions, the high performance design is also expected to find extensive use in military airborne and ground support equipment.

The all stainless steel sheet construction of the block assembly, including the hemispheric combustion chambers, cylinders, water jacket, intake and exhaust ports, upper oil pan and spark plug tubes, provides rapid and uniform heat dissipation, superior strength and low weight, and corrosion resistance —even when salt water is used to cool the engine in marine installations. The unique block design eliminates the head gasket, and permits very high compression ratios (12 : 1 standard; 14:1 optional) without problems.

Because the stainless steel sheet used to form the various block components can be held to a uniform wall thickness, the even cooling prevents "hot spots". The thin gauge stainless steel sheet (0.090 in.) used for the combustion chamber and ports dissipates heat several times faster than a cast block engine, and the tendency to pre-ignition "ping" is substantially reduced. A 0.063-in. liner of AISI 4130 steel is brazed in each cylinder to provide exceptionally low wear and long engine life. Because pressures and stresses are less severe at the outer cooling jacket walls, these are fabricated of 0.050-060 in. stainless.

Thin-gauge (0.050-0.090 in.) stainless steel is formed and brazed to provide a light, tough, corrosion-resistant engine block for the Tyce engine.



E.M.D. 3987 for further information

NICKEL ALLOY STEELS

ensure reliability underground

Huwood Slicer Loader and P.80 Conveyer

Mechanised coal mining involves the use of much highly developed power-driven cutting and loading machinery. Notable producers include Hugh Wood and Co. Ltd., Gateshead, who are pioneers in this field.

In the 'Huwood' Longwall Loading Machine, nickel alloy steels are used for stressed components to ensure continued reliability in underground working. The steels used for these components include the well-known nickel-containing compositions: En23 and En25 for face loader; En24 — slicer loader and 'Python' gearbox; En33 — pneumatic pick barrels; En36 and En110 — tail shafts for PA/5, CF chain conveyors.

TYPICAL MECHANICAL PROPERTIES OF

EN23

SIZE	HEAT TREATMENT	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
5⅛ in.	Oil quenched 830°C tempered at 630°C	65	19	57
2½ in.	Oil quenched 830°C tempered at 560°C	68	17	43

By utilising the better properties obtainable in more highly alloyed nickel steels, dimensions can be reduced, lighter constructions produced, distortion through heat treatment minimised and reliability and economy achieved.

Please send for our publications entitled, 'The Mechanical Properties of Nickel Alloy Steels' and 'The Case Hardening of Nickel Alloy Steels'

TGA 21/3/18

MOND NICKEL

THE MOND NICKEL COMPANY LIMITED, THAMES HOUSE, MILLBANK, LONDON, SW1

Grain Oriented Alloys by Powder Metallurgy

POWDER METALLURGY is a convenient method of preparing small batches of alloys of high purity and precise composition. It is being used at the Post Office Research Station, Dollis Hill, to prepare samples of grain oriented 3¼ per cent silicon-iron to study the formation of the (110) (001) ("roof top") and (100) (001) ("cube") textures.

Although silicon-iron with the "roof top" texture has been available to electrical engineers for many years, it is only comparatively recently that methods have been developed for inducing the formation of "cube" texture in the alloy. So far as is known, no such material is yet available commercially in any part of the world, although work on this problem in the U.S.A. and Russia has been reported. The advantage of material with the "cube" texture over that with the "roof top" texture is that two directions of easy magnetisation, at right angles to each other, are available, instead of one.

In order to obtain a grain oriented alloy, accurate control of the dew point during the sintering process has been found necessary. Then, by a combination of rolling and accurately controlled annealing schedules, either "cube" or "roof top" texture can be obtained. At the moment the hysteresis loss of these materials is a little higher than the equivalent material produced by the conventional melting process, but further research may point to the reason for this and enable a lower loss material to be produced.

Work is also being done on 16 per cent and 4½ per cent magnetic aluminium-iron alloys, which are said to be easier to produce by powder metallurgy than by the complicated melting method. Again, by special rolling and annealing schedules, grain oriented alloys can be produced.

Welding Design Service

IT HAS BEEN REPORTED by the British Welding Research Association that, although its design advisory service has only been functioning since November 1959, it has already handled a number of interesting projects. These include the design of a laundry press frame, grain storage bins, and an articulated grain carrying vehicle. There have also been several enquiries on the design of various parts of agricultural implements, and further enquiries on the design of earth-moving machinery such as crawler shovels, dumpers, and loaders.

Effect of Organic Compounds on Metal Fatigue

THE NATIONAL BUREAU OF STANDARDS has recently investigated the effects of polar and non-polar organic compounds on metal fatigue, in a programme sponsored by the National Aeronautics and Space Administration. The experiments showed that coatings of long-chain polar substances greatly increase the fatigue strengths of steel, magnesium, and copper-beryllium alloys. On metal surfaces the polar compounds apparently form tightly packed monolayers that act as a barrier to water and oxygen molecules. These results are expected to have practical application in extending the useful life of certain metals and alloys.

A magnesium specimen is coated with dodecyl alcohol before being fatigue tested. An uncoated specimen, used as a control, can be seen in the fatigue-testing machine in the foreground.

It is well known that environment influences metal fatigue. Even the mild corrosion that occurs when fatigue tests are run in a laboratory atmosphere may affect test results. A number of studies have shown that certain types of organic compounds afford protection against corrosion under normal unstressed conditions.

All of the experiments were conducted on rotating-beam fatigue testing machines of the R. R. Moore type, which apply pure bending moments to the test section. Specimens of six different alloys were tested to fracture under one of the following conditions: cleaned and dry; coated with or immersed in an organic substance; immersed in water, either in the coated or uncoated condition.

The water and non-polar liquids either had no significant effect or caused a decrease in the fatigue life of the specimens. The polar organic compounds, however, caused an increase of over 600 per cent in the fatigue life of the magnesium alloy, stressed at 12,500 p.s.i.; an increase of approximately 250 per cent in the copper-beryllium alloy, stressed at 50,000 p.s.i.; and an increase of approximately 200 per cent in the steel alloy, stressed at 100,000 p.s.i. These compounds had little, if any, beneficial effect on the other three alloys, titanium, aluminium, and stainless steel, probably because of the strongly adherent oxide films that form on these materials.

The results showed no appreciable difference between the specimens that were immersed in the polar substances and those that were merely coated with them. Coating the specimens with one of the substances, dodecyl alcohol, and then testing in a tap-water environment resulted in as much improvement as had been obtained with specimens tested in air.

Compounds having chain lengths of 8, 12 and 18 carbon atoms were studied. Of these substances, those having 12-carbon chains apparently gave optimum conditions. The comparison also showed that the type of polar group does not appear to be as important as the number of carbon atoms in each molecule.

THE DECEMBER ISSUE

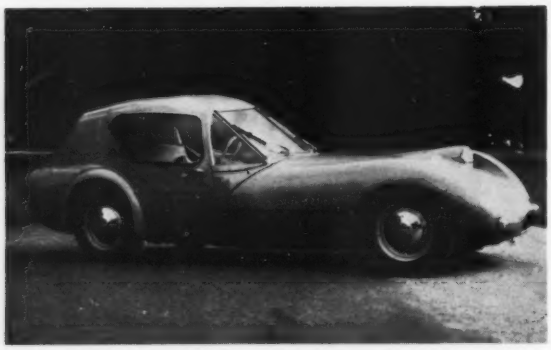
of *Engineering Materials and Design* will include the following main features:

Design and Application of Externally-pressurised Air Bearings
General principles, design data and typical uses.

Diesel Engines up to 300 b.h.p.: Part 2
Design features and tabulated data—concluding section.

Safety in Machine Design
The designer's responsibility; and influence of increased mechanisation.

Corrosion of Metals
Prediction of, and protection against, all types of corrosion.



The Marcus G.T. sports car, designed on aircraft principles with a wooden body-chassis unit.

Wood Chassis for Sports Car

THE NEW MARCOS G.T. has been designed not merely to provide the sports motorist with a lively well-mannered motor car, but also with a vehicle capable of putting up trophy-winning performances in the competition field. This car recently achieved nine first places in nine consecutive competition events.

Designed by Frank Costin, of Vanwall and Lotus fame, in conjunction with Jem Marsh, of Speedex Ltd., the car is built of spruce and laminated plywood, giving it an ultra-rigid body-chassis unit. The specially treated marine plywood, which does not easily fatigue, is fireproof, impervious to extremes of temperature, and in case of damage said to be easily repaired using Aerolite glue and plywood.

Constructionally, the accent is on safety. Independent front suspension, hydraulic coil spring damper units, rack and pinion steering and an extremely low centre of gravity are some of the features which add emphasis to the remarkable grip-tight roadholding qualities of this race-bred two-seater closed sports car. The monocoque integral construction is another of the safety features inherent in its design—features which have been fully developed and rigorously tested.

Being hinged at its front end, the complete bonnet assembly lifts to reveal a very accessible front end layout. Mechanical components requiring routine maintenance are easy to get at, with the minimum of inconvenience.

Symposium on Materials Sciences

ONE OF THE THINGS discussed at the A.S.T.M.'s 63rd Annual Meeting was ductile ceramics. According to Prof. Earl R. Parker, of the University of California, ductility has been observed in many nonmetallic crystalline materials. As in metals, the ductility or plastic flow in nonmetallic crystals occurs by the movement of dislocations along slip planes. Likely candidates for study among the ionic crystals are those with cubic structures, since they have a high degree of symmetry with numerous slip systems, and plastic adjustment at grain boundaries can occur without crack formation. Examples are the alkali halides, silver halides, and magnesium oxide. The last offers especially interesting possibilities, for it is ductile at room temperature and does not show surface effects as do the alkali halides.

While there are a number of possible sources of dislocation that can be caused to move on application of stress, a major one, according to Prof. Parker, is the presence of small foreign particles. Whilst dislocations are necessary for ductility, strength can be developed only by placing barriers in the way of dislocation movement, making slip more difficult. Very effective barriers, it has been observed, are networks of dislocations. These networks have been shown to be formed generally by stresses due to temperature gradients or restraints imposed on objects, such as by mould walls, etc.

Another session was devoted to discussions on the nature and origin of strength of materials, with particular attention to the properties of crystalline solids. Whilst the mechanisms of crack formation and fracture are not yet fully explained, there is good evidence that cracks may be started at points where dislocations pile up, such as at grain boundaries and slip bands. After the crack is formed, however, a certain energy is required for propagation, and a crack does not necessarily result in fracture. Whilst this observation was made by Prof. Parker in the first session, it sounded the theme for the second. Experts drawn from academic, industry and government research groups spoke on dislocations, fatigue, creep and fracture, and size and shape effects.

High-Temperature Nickel-Aluminium Coatings

THE NATIONAL BUREAU OF STANDARDS, in a programme sponsored by the Wright Air Development Center, has developed a method for producing nickel-aluminium alloy coatings capable of protecting metals from oxidation at temperatures up to 1000 deg. C. The coatings can be used to advantage on many types of aeronautical equipment. The most durable coating was obtained by electroplating nickel over the basis metal and then plating aluminium on the nickel at 700 deg. C.

Although cast nickel-aluminium alloys have good corrosion-resistance to atmospheric exposure and maintain their hardness at elevated temperatures, their brittleness prevents them from being fabricated into intricately shaped components. However, by utilising the alloy as a coating—rather than as a basis metal—and electroplating it on more ductile metals, an effective corrosion-resistant material can be obtained.

The most satisfactory procedure consisted in electrodepositing nickel from a Watts type of bath, i.e. a mixed chloride-sulphate bath, and then electroplating aluminium on the nickel layer at a current density of 2 to 15 amp./dm^2. The aluminium was deposited from a fused salt solution containing a mixture of potassium chloride, sodium chloride, and cryolite (sodium aluminium fluoride) at 700 deg. C. At this temperature aluminium diffuses into the nickel layer, as it deposits, thus forming the alloy.

For objects which require coatings, but which cannot withstand the high temperature necessary to operate the cryolite bath, an alternative method for plating aluminium is used. In this procedure, aluminium is deposited over the nickel at 160 deg. C. from a fused salt bath consisting of aluminium chloride and sodium chloride, and then alloyed with the nickel by heating for a few hours at 500-600 deg. C. in air.

The coatings provide suitable protection for steel, nickel and molybdenum, and are probably applicable to other metals. Coatings 50μ (0.002 in.) thick protected steel from oxidation at 550 deg. C., but did not afford adequate protection at 1000 deg. C. because the iron diffused through the coating. Thicker coatings would probably be satisfactory.

Environmental Engineers

THE SOCIETY OF ENVIRONMENTAL ENGINEERS, formed just over one year ago with the object of bringing together environmental engineers, has successfully achieved its aim. Well over 100 members are now meeting regularly to improve the status of environmental engineering, and exchange information concerned with the development of equipment to withstand severe shock, vibration and other forms of environmental conditions.

In view of the growing importance of obtaining the maximum possible reliability of equipment in all fields of engineering, every effort is being made by the Society to promote a greater appreciation of the value of environmental engineering.

The programme for the coming winter includes: an informal discussion on "Shock Environment", one of the objects being to provide ample opportunity for members to partake in the discussion; and meetings on "Vibration Testing and Instrumentation of Large Stores", "Development of Accelerated Climatic Tests", and "Development and Testing of Small Electronic Components".

FOR FURTHER INFORMATION:—

Central Electricity Generating Board, Friars House, 157-168 Blackfriars Road, London, S.E.1.
Quasi-Arc Ltd., 213 Oxford Street, Bilston, Staffs.
Cryogenics, Carlton House, Great Queen Street, London, W.C.2.
William Mallinson & Sons Ltd., Thames Road, Crayford, Kent.
Ingersoll Ltd., 202 New North Road, London, N.1.
Tyce Engineering Corp., 809 "G" Street, Chula Vista, California, U.S.A.
General Post Office, St. Martins-le-Grand, London, E.C.1.
British Welding Research Association, Abington Hall, Cambridge.
National Bureau of Standards, Washington 25, D.C., U.S.A.
Speedex Castings and Accessories Ltd., 17a Windsor Street, Luton, Beds.
American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. U.S.A.
Society of Environmental Engineers, 42 Manchester Street, London, W.1.

MACHINE TOOLS RESEARCH ASSOCIATION

THE fact that British machine tool design does not appear to be making adequate progress has been mentioned in this journal before, and we are therefore specially interested to hear that a new research association is to be formed to serve the machine tool industry. It seems that at last a real effort is to be made on a national scale to stimulate activity in this important field.

Britain can no longer be regarded as the workshop of the world, and Lord Verulam, who is chairman of the British Institute of Management, said recently: "I believe that the future of Britain, and particularly perhaps of industrial Britain in its world context, still depends on the extent to which we are prepared to venture forth into the unknown."

Certainly research is essential if advances are to be made in good design, but its usefulness is not confined to this, for the other factors, management, productivity and costs, are all amenable to scientific control and experiment. Increasing industrial production in other countries is making it more and more necessary for us to develop highly specialised machine tools and allied equipment, such as electronic controls. This can only be carried out efficiently if all research is co-ordinated by a central body.

The new research association is being sponsored by the Machine Tool Trades Association, who took a leading part in the establishment of the Product Engineering Research Association nearly twenty years ago. Approximately 100 manufacturers of machine tools and closely allied equipment have undertaken to finance the new research association for the first five years. In terms of total effort this does not sound very much, but the size of an organisation is no criterion of its usefulness or efficiency. What really matters is that, in the early stages particularly, the available funds should be wisely distributed on projects which will give the maximum return most quickly. Spectacular but expensive long-term researches which bring no immediate benefit to the industry should not be allowed to fritter away the funds.

It has been stated that in order to avoid an initial delay while waiting for new laboratories to be built, appropriate and available existing research facilities throughout the country will be used. This is a wise decision for the additional reason that a considerable amount of work is already being carried out on machine tools by private companies, government departments and universities. Much of this work is unpublicised and most of it uncoordinated. Remembering that one of the most appreciated services offered by P.E.R.A. is that of information and abstracting work, it would seem reasonable to suggest that the first job of the new research association ought to be to organise existing information, which can then be distributed to its members. If it gets no further than a really efficient information service, the venture will still have been worthwhile, because engineers are always asking for technical data and guidance and the cost of running such a service need not be high, compared to that of running laboratories.

A research manager recently commented that it was sometimes easier to initiate a practical programme of research than to find out what had been done before. This is a scathing criticism of existing information services, and suggests that here is a subject which demands immediate attention. It is usually considered more important for an information service to be quick rather than comprehensive, but we are still waiting for the computer-controlled automatic information service which could well be both.

Dr. R. Weck, director of the British Welding Research Association, recently said that welding research in the U.S.S.R. was comparable in total effort with that in the U.S.A., but that the Russian work was more "purposeful". Let us hope that the new research association will be purposeful, and not too academic in its outlook.

The Editor

PROPERTIES OF RUBBER

As long ago as 1825 Brunel fitted a rubber transmission belt to an engine used in sinking a shaft for the first Thames tunnel. This article summarises the present state of knowledge for modern applications

by **D. F. AITKEN** *

RUBBER hose and rubber washers have been common ever since the invention of vulcanisation, and rubber springs for buffers and draw-gear have been standard railway practice for well over a hundred years; but the full acceptance of rubber as an engineering material is of much more recent date. It had its origin in the years following the First World War, when motor manufacturers began to install rubber engine mountings and flexible couplings as a means of reducing noise and vibration, and was greatly advanced by the development about the same time of an effective and practical method of bonding rubber to metal.

The rubber-to-metal bond, whether effected by the original method of brass plating or by newer techniques involving the use of isocyanates and other bonding agents, is a true chemical bond which can be at least as strong under tension or shear as the rubber itself. It solves the problem of building-in rubber parts to a metal structure, and its basic use is illustrated in such components as the flat rubber sandwich employed as an anti-vibration mounting, the bonded rubber cylinder used as a flexible coupling, or the shackle pin in the form of a simple rubber bush. On the other hand, there are many engineering rubbers, including an immense variety of seals, grommets, gaskets, O-rings, diaphragms and washers, in which no bonding is necessary.

In either case, rubber considered as an engineering material differs markedly from metal, and engineers accustomed to deal only with metal are apt at first to find the behaviour of rubber disconcerting. Up to a point, the physical properties of a metal can be controlled by variations in alloying, heat treatment and other techniques; but the range of such variations is limited. With rubber the range of physical properties obtainable by variations in compounding and vulcanisation may extend all the way from a hard, brittle ebonite through the tough, abrasion-resistant material of a tyre tread to a soft, springy rubber that can be stretched to more than ten times its original length without breaking.

When dealing with a metal, the engineer normally relies on a group of physical properties which can be comparatively easily defined and evaluated in data tables. With rubber, the numerical values obtainable for physical properties are seldom independent of the conditions of measurement. Because of the extent of the deformations involved in some forms of test, the material of the sample may be continuously changing. What is finally measured, therefore, is a highly complex property not easily definable in general terms, and every detail of the process of measurement is likely to have an effect on the result.

This does not mean that test results on rubber specimens are not reproducible. Over the last thirty years a large number of test methods have been devised, and reduced to sufficiently exact definition to yield tolerably consistent results, both as between one specimen and another and between one laboratory and another. Many of these have been accepted as British Standards and are published by the British Standards Institution as BS 903, *Methods of Testing Vulcanised Rubber*. Margins of error are apt to be wider than in metallurgical practice, test results are usually more difficult to relate directly to service performance, and the kind of uncertainty which metallurgists have to contend with in their efforts to measure fatigue is in the nature of a routine problem to the rubber technologist.

Tensile Tests

For instance, one of the oldest established tests for rubber consists in stretching a strip of the material till it breaks, and noting the tensile strength (defined as the force per unit area of original cross-section at the moment of rupture) and the elongation at break. Both these quantities

The heading illustration shows a mounting consisting of a rubber cylinder bonded between metal plates, subjected to a tensile force of 1,000 p.s.i. The rubber is extended to four times its normal length, but the rubber-to-metal bonds remain unaffected.

* *Federation of British Rubber and Allied Manufacturers.*

vary to some extent with temperature, but they may also vary with the shape and size of the test piece and with the rate of stretch.

The stress-strain curve, far from being approximately linear as for a metal in its elastic range, curves markedly towards the stress axis, and is significantly different for different kinds of rubber compound. There is therefore no simple relation between stress and strain corresponding to Young's modulus. Instead, "modulus" for rubber is defined as the force required to produce a given elongation in a test piece of uniform cross-section. In practice, moduli are most frequently quoted at some multiple of 100 per cent extension, say 300 per cent, while elongation at break may be anything up to 1,000 per cent for a pure gum vulcanisate, i.e., one containing no filler or reinforcing agent.

The fact is, however, that physical properties measured at these elongations have practically no direct relevance to any modern application of rubber except perhaps toy balloons and small boys' catapults. It is comparatively rare for an engineering rubber to be used in tension at all, and, if it is, the elongation almost never exceeds 50 per cent. Yet because tensile strength and elongation have been found empirically to be highly sensitive to any variation in compounding ingredients or vulcanising procedure, they have been used for many years in process control as a check on the state of vulcanisation and quality generally. Once a particular compound has been established as suitable for a given application, these tests can be used both by manufacturer and by customer to ensure that there has been no unintentional deviation from the specified quality.

Hardness and Compression Tests

A rough indication of the behaviour of any given rubber under compression can be obtained by using a hand instrument which measures hardness by the depth of indentation reached by a steel plunger under spring loading. The standard methods using a dead load on the plunger, such as those approved by the British Standards Institution and by the American Society for Testing Materials, give consistent results and are the only ones that should be used in product specifications. Simpler spring-loaded instruments are widely used in the industry to give a rough check on the type of compound and its state of vulcanisation: their readings must be taken as approximate only, since there is a fairly wide margin of variation between different instruments and different observers. Hardness values in the accepted British and International Rubber Hardness Degrees range from 30-40 degrees for soft pure gum vulcanisates to 95 degrees and more for a semi-ebonite.

More closely related to operational conditions are the stress-strain relations obtained by compressing a slab of rubber between steel plates. If the rubber surfaces in contact with the plates are prevented from slipping and so expanding in area, the stress expressed in terms of the original cross-section increases very rapidly as the compression is increased. This reflects the well-known fact that a rubber buffer builds up a rapidly increasing resistance to a compressive force and does not come to a sudden stop like a steel spring. Under compression the total volume of the rubber remains virtually unchanged, and the decrease in length is compensated for by bulging in cross-section. The stress-strain relation is therefore dependent not only on the elasticity of the rubber and the extent of deformation at any one time, but also on the geometrical shape of the specimen under test. Methods of calculating a shape function for the more common geometrical forms have been worked out, the general principle being that the apparent stiffness of the specimen will increase as the ratio of free (bulging) surface to load-bearing surface decreases.

For seals and gaskets of all kinds an important property is compression set, defined as the residual strain in a test piece after it has been subjected to a compressive stress for a given time and then allowed to recover for a given time. In BS product specifications the stress is normally applied for 24 hours, and the residual strain measured 10 minutes after the stress is released. For a fuller evaluation of a rubber, additional recovery periods are used, thus giving an indication of the complete recovery curve. The original deformation may be applied in conditions either of constant stress or constant strain. Set can be measured both in tension and in compression, but the results for compression set are more representative of service performance than those for tensile set.

Closely related to set are the phenomena of creep (the gradual increase with time of the strain produced by a constant stress) and stress decay or relaxation (the decrease with time of the stress required to maintain a constant strain). If rubber is looked upon as showing some of the properties of both a liquid and a solid, i.e. both viscous and elastic behaviour, the set may be taken as representing the viscous element in its behaviour under long-term loading, while creep and stress relaxation represent a combination of viscous flow with changes in the molecular structure induced, for example, by oxidation. All three properties vary extensively and often rather unpredictably with temperature, so that for components which have to stand up to high temperatures in use, laboratory tests at elevated temperatures, as well as at the usual 20 deg. C., are required.

When rubber is stressed in shear it is more flexible than in compression, and the stress-strain relation is much more nearly linear. For this reason, most anti-vibration mountings are designed to make use of the rubber either wholly in shear or in combinations of shear and compression, so arranged as to give different stiffnesses in different directions or to allow the element of compression to become progressively more effective under the incidence of shock loads.

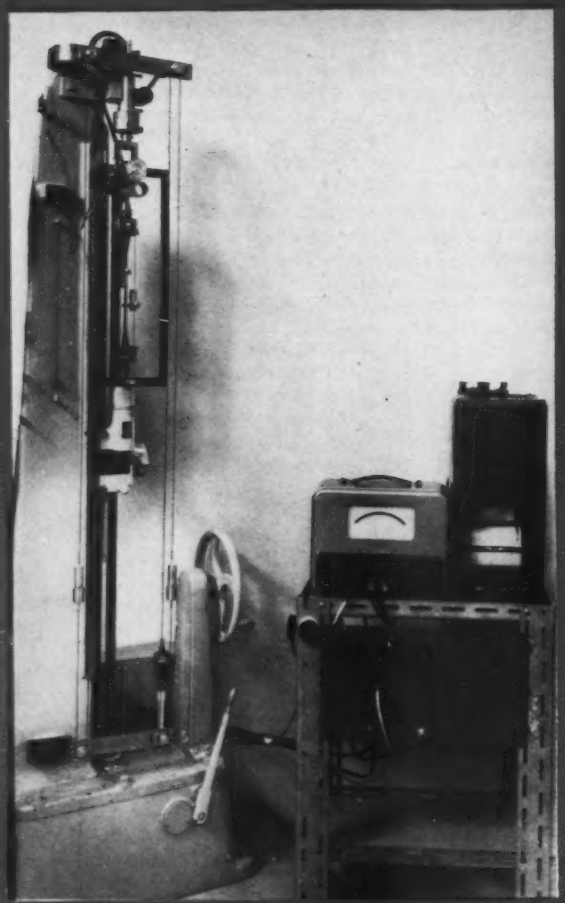
Static and Dynamic Properties

Because of the time factor in the response of rubber to an applied load, measurements of the various moduli, in extension, in compression and in shear, are always higher under dynamic than under static conditions. Theoretically, at very high frequencies, the rubber would behave like a rigid solid. Over the frequency range normally met with in engineering applications—say up to 150 c/s—the dynamic moduli of a natural rubber compound remain relatively constant, their ratio to the corresponding static moduli being anything from 1·1 for a soft, highly resilient vulcanisate, to about 2 for a stiffer material; but with the oil-resisting synthetics this ratio may be up to 4 or more for a compound of comparatively low resilience.

Resilience represents the ability of a piece of rubber to return the energy used to deform it during its recovery from deformation. It is usually measured with a machine in which a striker carried on some form of pendulum hits the test piece and rebounds. The relative extent of the rebound gives a measure of the rebound resilience, and values up to about 90 per cent are obtained with some types of natural rubber.

The energy lost in the process of deformation and recovery (hysteresis) is converted into heat, so that the lower the resilience of a rubber the more rapidly it will heat up under repeated deformations such as those to which a tyre or a driving belt is subjected. Normally, hysteresis is deduced from the rebound resilience, but it can also be found from the area of the loop enclosed between the loading and unloading curves, or by measuring the rise in temperature after rapidly repeated deformation cycles.

In this pendulum machine for measuring resilience, the test piece is mounted on the pillar and hit by a hammer carried on the triangular pendulum.



A tensile test machine in which the elongation is recorded electronically.

Service Life

Of considerable importance in engineering is the length of time for which a rubber component can be expected to remain serviceable. In favourable circumstances this can often be remarkably long. On dismantling Victorian railway stock, for instance, buffer springs have been found still resilient after fifty and even sixty years of service. For engine mountings in a motor car, twenty or thirty years of continuous service is not unusual, and even in the severe conditions which modern flying imposes, some aircraft components will last as long as the aircraft itself.

Natural rubber is subject to a slow deterioration by oxidation, and this process is greatly accelerated by heat and by sunlight. Surface cracking can arise in stretched rubber by the action of the ozone in the atmosphere. In the last thirty years a number of highly efficient anti-oxidants and anti-ozonants have been developed which, when included in the mix before vulcanisation, serve to retard very considerably the processes of deterioration, even in adverse circumstances. Moreover, some of the synthetic rubbers, such as neoprene, Hypalon and butyl, are much more resistant to sunlight, ozone and weathering generally than natural rubber, and are now regularly used where prolonged exposure to these conditions is unavoidable. Other synthetics, such as the silicone rubbers, have outstanding resistance to heat.

To test the relative resistance of any particular compound to normal oxidative deterioration, a number of accelerated ageing tests have been devised in which specimens of the compound are exposed to prolonged heat at, for example, 70 deg. C., either in air at atmospheric pressure or in oxygen at 300 p.s.i. These tests give a useful indication of how well a compound is likely to stand up to ageing in the dark, but a good deal of caution is required in the interpretation of the results in terms of probable service life.

Closely associated with ageing, but essentially distinct, is deterioration from fatigue. Static fatigue, marked by sudden failure under prolonged stress, is largely unpredictable, though it is known that highly resilient rubbers usually show good resistance to fatigue, so that such failure is very unusual. It is also known that the chance of failure is increased by high temperature, by over-vulcanisation, by local stress concentrations, and by oxidation, ozone attack and other forms of chemical deterioration. Dynamic fatigue, or failure under oscillating stresses, depends also on these factors, but the fatigue life has been found to be noticeably longer if the rubber remains strained throughout and at no point in the cycle passes through the position of complete relaxation.

In many applications the ability of the rubber to resist tearing is important, and much effort has been expended on devising a test for tear strength which will give reasonably useful and consistent results. In the method now generally accepted a crescent-shaped piece of rubber is used, a nick or slit 0·020 in. deep being cut at right angles across the concave edge; this is then stretched in a tension testing machine until tearing starts and spreads from the nick. Tear strength is considerably affected by the lie of the grain, and is much improved by the addition of carbon black and other reinforcing agents.

The tendency of rubber to fail under repeated flexing is measured by subjecting grooved test pieces to flexing in one or other of several machines designed for the purpose. At intervals the machine is stopped, and the surface of the rubber in the grooves compared with standard photographs and descriptions to determine the degree of flex cracking which may have developed. The cut growth test is similar, except that an initial cut is made in the test piece.

There is also the problem of abrasion. Many attempts have been made to devise a laboratory test which will correlate with the resistance to abrasion shown by rubber in actual service, but no generally satisfactory method has

been found. Laboratory tests have a certain limited value in sorting out closely related compounds, but they are apt to give highly misleading results when different types of rubber are compared, e.g., natural with SBR, or one synthetic with another. Moreover, the kind of rubber which provides the highest abrasion resistance on the heels of women's shoes is quite different from the kind required for tyre treads, on the one hand, or for the lining of sand-blast hose on the other. Nevertheless, though quantitative standards of abrasion resistance have so far eluded the ingenuity of the technologists, a great deal is known in a qualitative way about the behaviour of different compounds under abrasive conditions, and this knowledge is constantly being kept up to date and expanded by carefully planned and exhaustive service tests.

Oil and Chemical Resistance

Natural rubber swells and weakens in mineral oils, and in a number of organic liquids such as petrol. Several of the special-purpose synthetics are in varying degree oil resistant, notably neoprene, the nitrile rubbers and the thiokols, while some of the newest synthetics such as the fluorocarbon rubbers and fluorinated silicones have been specially evolved to resist hot oils at temperatures up to 200 or 250 deg. C.

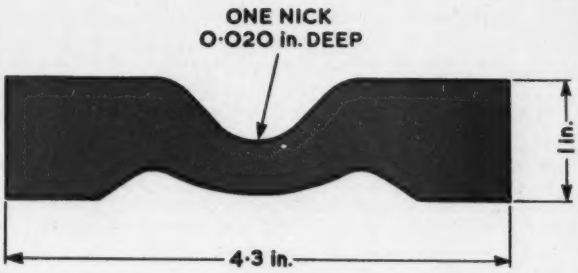
Assessment of the oil or solvent resistance of a rubber compound is a relatively simple operation. Test pieces are immersed in the liquid for a given period of time at a given temperature and weighed before and after swelling, both in air and in the liquid. From the four weights the percentage increase in volume can be calculated. Increases in volume of 100 to 200 per cent are not uncommon for natural rubber immersed in hydrocarbon oils at room temperature for a day or more. The amount of swelling which can be tolerated in any particular application will, of course, vary, but values below say 15 per cent are usually taken as indicating satisfactory resistance, and where doubt arises physical tests on the swollen material may help to resolve the question.

Similarly, the resistance of various rubbers to other chemicals, such as salts, acids, dyes, bleaches and other oxidising agents, and the new refrigerating and hydraulic fluids, can be estimated by immersing samples in the liquid for appropriate periods of time and then applying the relevant physical tests. Chemical resistance becomes of paramount importance when rubber is used for the protection of chemical plant of all kinds against corrosion. It is also of importance in the manufacture of hose for handling chemicals including the new hydraulic and refrigerating fluids.

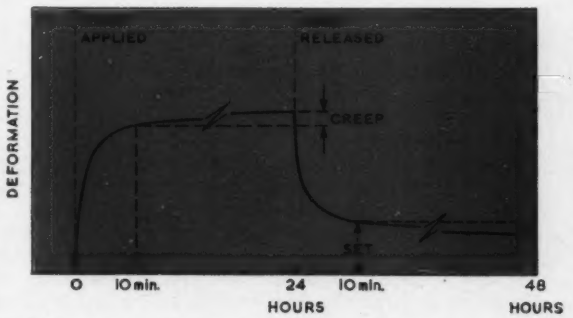
Designing Rubber Components

These, then, are some of the ways in which rubber technologists over the last twenty or thirty years have set about defining in quantitative terms the complicated behaviour of natural and synthetic rubber compounds. The list is by no means complete. It omits all the electrical tests appropriate where rubber is used for insulating purposes, or alternatively where conductive rubber is required for the dissipation of static. It omits such considerations as low temperature resistance, permeability to gases and to liquids, heat and sound conductivities and resistance to bacterial action. It says nothing of the special properties of cellular rubbers and expanded ebonites, or of questions such as adhesion and ply separation which arise when rubber is used in conjunction with natural or man-made fibres. It should be sufficient, however, to give some idea of the difficulties involved and the ways in which they have been progressively overcome.

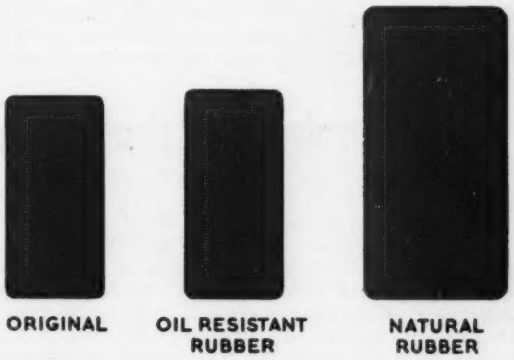
For the most part, the methods now employed yield results which are reasonably reproducible, but the significance of which is relative rather than absolute. In designing a rubber component for a new application, therefore, the



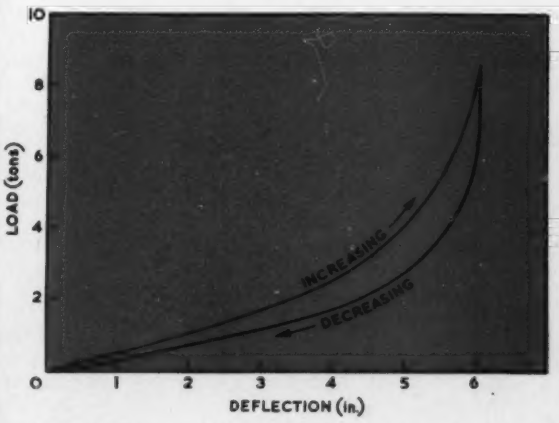
Standard shape of test piece for measuring tear strength.



Deformation and recovery curve for rubber under compression.



Swelling of natural rubber and of an oil-resistant synthetic rubber after immersion for 2 weeks in a test fluid at 70 deg. C.



Load-deflection curve (showing hysteresis loop) for a railway buffer spring under compression.

procedure is first to define as clearly as possible the job it has to do, the conditions to which it is likely to be exposed, and the performance required. At this point an experienced rubber technologist will be able to form a good general idea of the kind of compound needed. If an unusual combination of properties has been called for, he may want to make a number of samples of experimental compounds, and apply the appropriate tests in order to discover which best meets the special requirements. After that, specimen components are made from the chosen compound, and thoroughly tested in as near an approximation to service conditions as can be devised. In practice a number of specimen components may have to be tested in this way before a final choice is made. Then, when the best compound has been found and proved, there remains the task of setting out specifications which will be as simple as possible while still adequate to ensure reproduction of the essential qualities of the compound through process control, and subsequent checking.

Specifications

It is in this problem of specification that the very rapidity with which rubber technology has developed in the last twenty or thirty years has led to increasing difficulties. The busy design engineer has neither the time nor the facilities for keeping abreast of every new development, and if he tries to write his own specifications merely from general principles or past experience, he may well make it impossible for the rubber manufacturer to provide him with the material he most requires.

A lot of trouble, for instance, arises from the vague theory that high tensile strength is synonymous with superior quality. On this principle customers have specified high tensile strength for oil seals where the demand is not only irrelevant but may necessitate the use of a rubber with quite unsuitable properties in other respects, and rules out the synthetic rubbers which alone can provide the best oil resistance. Any practising rubber technologist could give many instances from his own experience of specifications calling for entirely irrelevant properties, which at best are liable to put the price up and, at worst, may be completely incompatible with the optimum properties really required. He will also have been plagued with demands for non-standard tests when the standard tests for which his laboratory is equipped would have been equally effective, and he will have met, not once but many times, the naïve absurdity of "best quality red rubber".

It is in the hope of rationalising some of this confusion that the Federation of British Rubber and Allied Manufacturers has recently set up a Federation Specification Advisory Committee which users can consult when working out specifications for engineering components. The Committee has drawn up a Guide to the Drafting of Rubber Specifications for engineering components, and lays stress on the necessity for consultation at the earliest possible stage between engineers designing rubber components and technologists in the firms which will be called on to manufacture them.

Such early collaboration is essential if the best—and cheapest—compound is to be found for any new application, and it may be equally valuable in helping to reach the best and most economical form for the design itself. Situations frequently arise in which a slight modification may enable a standard form of bush, seal, mounting or coupling to be used with consequent saving in trouble or expense; or it may be possible by a slight change in the shape of a component, which an experienced rubber technologist would suggest, to reduce considerably the cost of manufacture, and sometimes to improve the ultimate performance as well.

NOISE CAUSES FATIGUE IN METALS

ACOUSTICAL, or sonic, fatigue is a child of the jet and rocket age. Noise levels produced by the powerful blast of a jet exhaust are high enough to excite damaging vibrations in the airframe structure. It is estimated that about 1 per cent of the energy in the fuel of a large jet engine is converted into sound—this means that sound energy is produced at the rate of about 50,000 watts. Furthermore, this noise covers a random, broad frequency spectrum that includes most of the important modes of vibration of airframe structures. At some of these frequencies, millions of stress cycles can be accumulated in a matter of hours.

Many problems are posed by this upstart phenomenon —some old, mostly new: (1) how to predict or measure the noise spectrum to which a structure is exposed; (2) how to determine the stresses and vibration modes produced by that noise; (3) how to predict the fatigue life under such random loading; (4) how to verify that prediction; and (5) how to design for increased fatigue life. All these problems were touched on at the Symposium on Acoustical Fatigue presented at the 63rd A.S.T.M. Annual Meeting in Atlantic City, N.J., June 26 to July 1, 1960.

Papers entitled "Fatigue of Structural Metals under Random Loading" and "The Fatigue-damaging Effect of a Random Load" wrestled with the statistical aspects of random loading, and proposed methods for correlating results from variable-amplitude fatigue tests with those from constant-amplitude tests. Since the latter are much easier to make, and since there is already in existence a vast body of data from such tests, it will benefit engineers to find a way to make use of constant-amplitude test data in random-load situations. In the first paper the author attacked the problem in terms of an "interaction" between infrequent high-stress amplitudes and the dominant low-stress amplitudes, and introduced an "interaction factor", with the aid of which he demonstrated the validity of a pseudo-linear rule of cumulative damage for structural aluminium. The second paper discussed certain parameters for specifying a random load and suggested that fatigue tests run with systematic variation of these parameters may be used to correlate with results from constant-amplitude tests.

Equipment for acoustical fatigue testing is still under development. At present, the only reliable test is one that takes place in the actual service environment—behind an operating jet engine. Although this is almost prohibitively expensive, it is still the most common test for final approval of a structure. Some equipment is now being developed in industrial and government laboratories for use in development testing of structures. Sirens are now widely used, although the results from tests with these noisemakers must be modified to account for the fact that only one frequency is produced, and thus only one mode of vibration excited. High-intensity sirens producing randomised tones are, however, under development. Other types of exciters in use are air blasts, air jets whose pressure is modulated by movement of a loudspeaker voice coil, and model jet engines.

A paper entitled "Material Properties which Affect Acoustical Fatigue Life and the Role of Damping" concluded that the most hopeful avenue to explore in the search for methods to strengthen structures against acoustical fatigue is to increase damping. Much can be done toward working out design concepts that use to the fullest the damping inherent in the structure itself; examples of this are material hysteresis, rubbing at contact surfaces, and shear in adhesives.

EFFECT OF NEUTRON IRRADIATION ON THE TRANSITION TEMPERATURE OF STRUCTURAL STEELS

by N. L. PARR, F.I.M., A.M.I.Mech.E.

Results are given of a joint investigation, by A.M.L. and U.K.A.E.A., into the mechanism of irradiation damage to structural steels

MILD and low alloy steels occupy an important place in the range of metals and alloys used in the construction of nuclear reactors. Not only are they the only materials available in the massive forms often required, but methods for their fabrication into often quite complex shapes are fairly well established and understood by those engaged in reactor design and construction. Some idea of the vessel sizes which are often involved can be gained from study of some of the reactor designs now being considered. These call for structures ranging from thick-walled reactor pressure vessels to large spheres for complete reactor containment. Possibly the best known of these is the large spherical chamber which has been constructed for the fast reactor at Dounreay. Mild steel is generally used for the calandria, or vessel which contains the core and primary coolant, and in cases where water at high pressure and high temperature is used as the moderator and primary coolant it is necessary to fabricate the pressure vessel from thick steel plates by welding. Mild and low alloy steels are also frequently chosen for many other components of reactor design.

Depending upon their location and function, these steel components are subjected to a wide range of operating conditions imposed by temperature, stress, neutron irradiation and various corrosive environments. While a combination of some or all of these conditions is encountered during reactor operation, it is convenient to study each one separately. Much is already known of the effect of temperature, stress and corrosive environment on steel, but neutron irradiation has imposed a new service condition about which little is understood. It is quite possible that creep and fatigue resistance, tensile strength and ductility could all be affected, and an investigation to study the extent of irradiation damage has to take into account a range of neutron dosages for various temperatures and over various times of exposure. While gradual deterioration of reactor components would be very undesirable, a sudden catastrophic failure could be disastrous. The property of mild steel which is being closely studied in this connection, therefore, is its inherent resistance to crack propagation—the possibility of this being adversely influenced during reactor operation is being studied by observing changes in transition temperature consequent upon radiation damage.

This property of steel is known as the transition temperature, and is the temperature at which its normal ductility is replaced by a characteristic brittleness which permits fracture to occur in a sudden extensive way with little absorption of energy, and which can result in the complete collapse of a steel structure such as was encountered in the Liberty ships during World War II.

The point at which mild steel loses its apparent ductility may be spread over a range of temperature, as shown in Fig. 2. The various tests which are employed for its measurement may indicate somewhat different transition temperature ranges for any given steel, but they usually place results on a series of steels in the same logical order. Degree of brittleness may be assessed by observing the appearance of the fracture surfaces. The characteristic cleavage fracture of a brittle failure is quite distinct from the normal fibrous characteristics of a fractured tough material, as can be seen in Fig. 2, which shows fractures of the same steel occurring at various temperatures separated by roughly 5 deg. C. intervals.

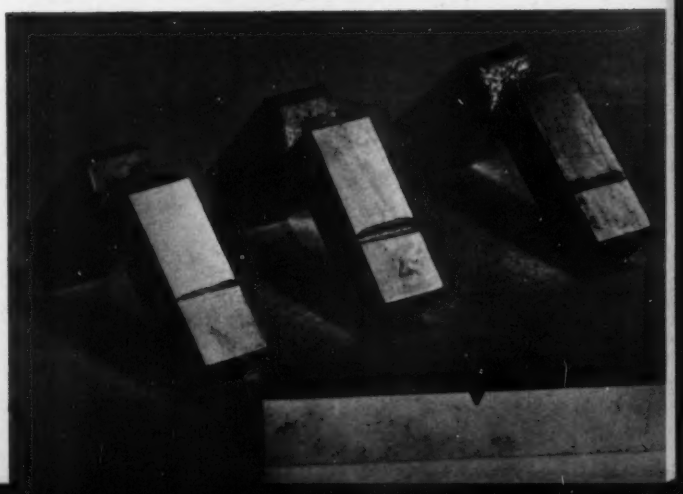
Acceptable levels for transition temperatures in steels are normally based upon the temperatures which may reasonably be expected during service life, allowing for a margin of safety. In the case of nuclear reactors, not only must provision be made for the original inherent transition temperature of the fabricated steel to be low (particularly where construction is carried out on an exposed site), but also for the possibility of the transition temperature being raised by radiation damage to levels at which fracture may occur during subsequent shut-down periods.

It has now been well established that the consequence of irradiating mild steel with fast neutrons is to raise the yield point and ultimate tensile strength whilst reducing elongation and reduction of area. The effect on notched impact tests is to raise the transition temperature substantially, lower the "energy-to-fracture" values, and increase the hardness.

Test Procedure

Although some tests are designed to resemble service conditions as closely as possible, it was decided for the present work to adopt a simple form of test which had previously been employed for brittle fracture investigations at the Admiralty Materials Laboratory. This particular test is termed the "slow bend notch test" and has many advantages to recommend it where radioactive specimens are involved, and where the main object of the investigation is to observe a change in transition temperature.

Fig. 1. Appearance of test pieces before and after the slow bend notch test.



* *An earlier specification, BS 649: 1949 quoted the rating over a period of 12 hours, and manufacturers should be consulted to confirm that their ratings do conform to the latest specification, i.e., BS 649: 1958.*

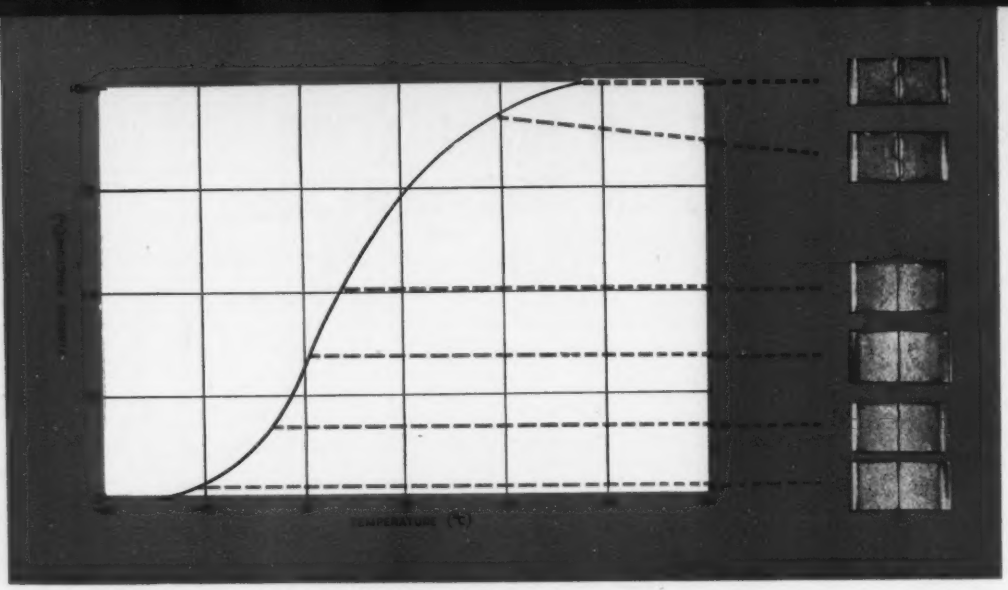


Fig. 2. Typical transition curve for mild steel, based on fracture appearance.

The example given in Fig. 2 illustrates how a typical transition curve can be plotted by visual assessment of the ratio of toughness to brittleness in the fractured surfaces. Details of the test chamber and loading device are shown in Fig. 4. Precise test temperature levels from +95 deg. C. to −95 deg. C. are selected, and maintained by circulating temperature-adjusted fluids through the chamber and around the test piece from suitable heat exchangers. The load is applied at a constant rate to the point of fracture, and the appearance of typical test pieces before and after fracture can be seen in Fig. 1.

Opinions are divided as to which degree of brittleness exhibited by the fracture should constitute the actual transition temperature of the material, but as the present investigation is aimed at observing a change rather than values, it was decided to assess this at a 50 per cent brittle appearance. More recently it has been shown that assessment of the transition temperature at a 5 per cent crystalline fracture appearance is more in line with larger scale tests.

The survey of each plate for its inherent transition temperature must take into account variations through the plate, and differences brought about by the deposited weld metal and the heating of adjacent zones. Groups of specimens were prepared from each representative position, and a Standard Izod V notch was machined in the centre, across the direction of rolling, from the unirradiated plate, for initial evaluation. Corresponding groups of specimens were prepared from the same plate for the irradiation and strain-ageing studies. The effect of long-term soaking at reactor temperatures was also included in the out-of-pile studies.

In the case of the strain-ageing trials, specimens were prepared so that 5 per cent, 10 per cent, 15 per cent and 20 per cent strain could be given to the test material, both by compression and tension straining, followed by ageing at 200 deg. C. for 1 hour. Standard size test pieces were then prepared from this material for assessment of transition temperature.

Irradiation facilities were selected so that variations in neutron intensity and temperature of irradiation would give two different total integrated neutron fluxes over two periods of time at two temperature levels. Two integrated neutron dosages, 5×10^{19} n/cm.^{2} and 10^{20} n/cm.^{2}, were achieved over periods of three and nine months respectively, each at temperatures of 50-60 deg. C. and 130-140 deg. C.

Results

Two steel compositions were selected for this work. The first had a nominal composition of 1·2 per cent manganese, 0·5 per cent chromium, 0·25 per cent molybdenum and 0·15 per cent carbon, whilst the other was a plain low carbon steel containing 0·14 per cent carbon. The average transition temperature of a $4\frac{1}{8}$ in. thick plate of the low alloy composition was around 0 deg. C. After irradiation dosages of 5×10^{19} n/cm.^{2} and 10^{20} n/cm.^{2} at 50-60 deg. C., the transition temperature had been raised to +40 and +72 deg. C. respectively. The transition temperature of the same material, irradiated at 130-140 deg. C., had risen from 0 to +65 deg. C. and +77 deg. C. respectively for the two dosages. These results are shown graphically in Fig. 3.

The results of radiation on both the weld metal and heat-affected material showed similar tendencies to that of the parent metal but at different values. The rise in transition temperature of the parent plate caused by a combination of 10 and 20 per cent compression straining and ageing can

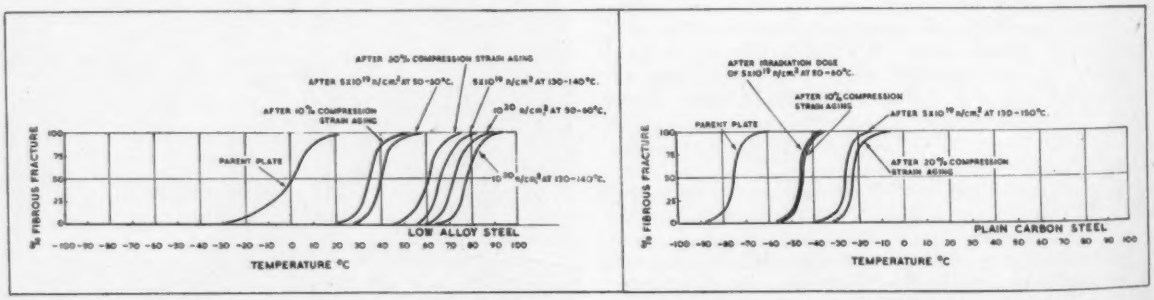


Fig. 3. Transition curves for two commercial steels, before and after irradiation and after compression strain ageing.

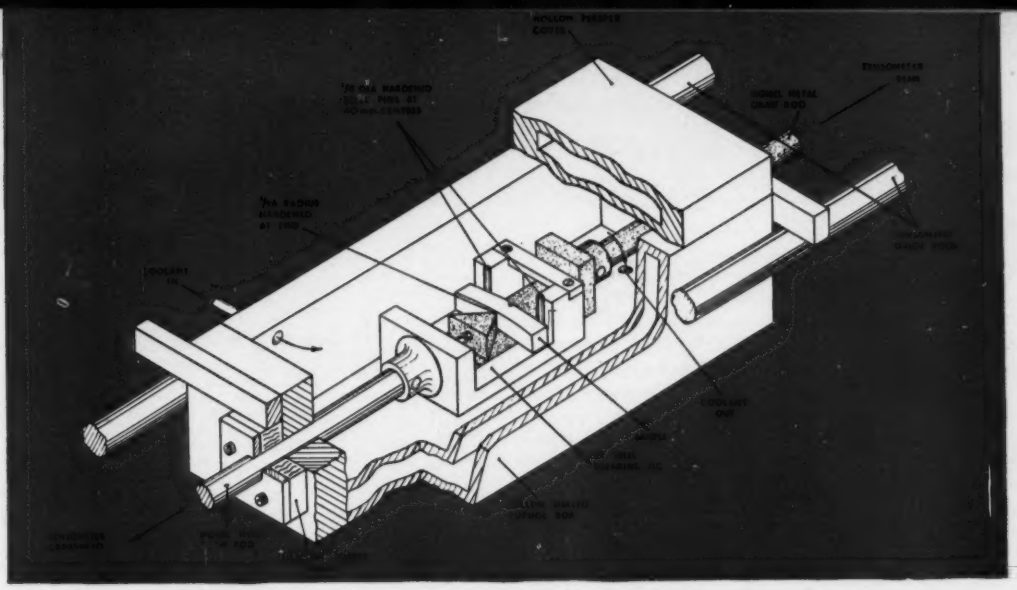


Fig. 4. Cooling chamber containing the slow bend jig.

be seen from Fig. 3 to be similar to that brought about by the 5×10^{19} n/cm.^{2} radiation dosage at the lower and higher irradiation temperatures respectively.

The inherent transition temperature of the low carbon was much lower than that of the low alloy steel, an average value for the parent plate being −75 deg. C. Irradiation at 5×10^{19} n/cm.^{2} at 50-60 deg. C. and 130-140 deg. C. produced rises in transition temperatures of about the same order, for the same conditions, as for the low alloy steel, namely to −45 and −25 deg. C. respectively. Rises in the transition temperatures of the weld metal and heat-affected zones showed similar tendencies, but again at slightly different values. As may be seen from Fig. 3, 10 and 20 per cent compression strain ageing of this material again gave somewhat similar increases in transition temperature to that brought about by the 5×10^{19} n/cm.^{2} radiation dosage at 50-60 deg. C. and 130-140 deg. C. respectively.

Transition temperature observations were supplemented where possible by hardness tests. Allowing for a considerable scatter in results, there was undoubtedly a significant increase in hardness due to irradiation, the magnitude of the increase in the low alloy steel being greater after irradiation to 10^{20} n/cm.^{2} than at 5×10^{19} n/cm^2, at 50-60 deg. C. The increase in hardness was greater still at 130-140 deg. C. in the case of the 5×10^{19} n/cm.^{2} dosage.

Conclusions

Although only preliminary results have been quoted in this article, they confirm that the primary consequences of neutron irradiation are to raise the ductile-to-brittle transition temperature and to lower the energy-to-fracture values of steels available for the fabrication of large reactor components by welding. These undesirable increases are substantial for the fast neutron intensities chosen for the preliminary studies. Results confirm previous observations made in the U.S., and extend the knowledge to show that irradiation temperature also plays an important part in the damage mechanism. This is demonstrated by the greater rise in transition temperature for the same integrated neutron flux produced at 130-140 deg. C. as opposed to 50-60 deg. C.

Other work has indicated that irradiation with an integrated neutron flux of 5×10^{18} n/cm.^{2} at 315 deg. C. has little effect, whereas a similar radiation dosage at 95 deg. C. produces a marked rise in transition temperature. This and the previous results suggest that there may be a peak in the irradiation/temperature relationship with regard to the transition temperature of a particular steel. This could be a very important factor in the selection of the most suitable composition for reactor vessels. The irradiation dosages selected for this test programme may be higher than those to which some vessels will be subjected in practice. It will be necessary, however, to proceed much deeper into this investigation, and to study the full influence of steel composition and physical constitution before steels for reactors can be chosen more precisely.

There appears to be some similarity between the adverse effects on transition temperature produced by a combination of irradiation and temperature and those produced by compression strain ageing. Further work will be required to show whether a useful relationship exists between damage imposed by different levels of straining and ageing and that produced by neutron irradiation, or by the combined effect of neutron irradiation and temperature. There may also be some common factors in the theoretical explanation of the structural damage imposed by radiation and that produced by the combination of straining and ageing.

With regard to the fundamental nature of irradiation damage, present theories suggest that such damage results from displacement of atoms from their equilibrium lattice position by fast neutrons creating vacant lattice sites and interstitial atoms. Such displacement would account for the observed increases in hardness, and would result in internal strain which would support rapid crack propagation. If such a mechanism is responsible for the damage, it could be influenced considerably by initial ferritic grain size, the nature and dispersion of impurities or the condition of constituent phases produced by deliberate alloying additions.

It is interesting also to speculate that the higher irradiation temperatures may encourage mobility of defects to positions where they may lock dislocations more favourably, thereby increasing hardness and reducing ductility.

Although the rises in transition temperature observed on the two steels selected were considerable, the plain carbon steel, in its welded form, still allows a margin of safety for reactor construction. Furthermore, it is confidently expected that it will be possible to produce steels in which the shift in transition temperature due to neutron irradiation is not so marked, or the actual transition is spread over a wider temperature range.

This article is published by permission of the Admiralty, and acknowledgment is given to colleagues at the Admiralty Materials Laboratory and workers in the Atomic Energy Authority for their help and advice.

NOVEL EQUIPMENT AT FARNBOROUGH

Miniature Air Liquefier

ON view at the recent Farnborough Air Show was the Hymatic Engineering miniature air liquefier. Though basically a research and laboratory tool, a modified version has found its way into some of the newer guided weapons, where it supplies small quantities of air for cooling purposes. An example of its use in the laboratory is in the field of semi-conductor research, where strange changes in physical properties occur with reduction in temperature.

This unit, which will also convert oxygen and nitrogen into liquid, is only a little over 4 in. long and about ¼ in. in diameter. It functions on the well-known Joule-Thomson effect, which causes a reduction in temperature by the throttling expansion of a gas below its inversion temperature.

There are no moving parts. Liquefaction is achieved by passing almost dry air (of the order of one part water per million parts air) at 1,500-3,000 p.s.i.g. and at room temperature through three helically-wound fine-bore heat exchanger tubes. These are mounted in a small vacuum flask which also serves as a receptacle for the liquid produced. Having passed through the coil the air is expelled through an ultra-fine orifice, producing an initial temperature drop of approximately 50 deg. C. The cooled air flows back over the heat exchanger, extracting heat from the incoming air. Progressive cooling in this fashion to −194 deg. C. results in a fine spray of liquid air being formed at the orifice. The exhaust air which is not converted to liquid is now only a few degrees below room temperature.

Once liquefaction occurs, after about 3 min. operating time, pressure can be reduced to 1,300 p.s.i.g.; this results in the most economic use of the air supply. A ½ cu. ft. capacity bottle initially charged to 4,000 p.s.i.g. will give 5 hr. continuous running.

Efficiencies (expressed as a proportion of the air converted to liquid) are rather low, but are more than offset by the relative simplicity and low cost of the unit. For air (bottle temperature 20 deg. C.), values of 1·7 per cent at 1,600 p.s.i.g. to 6·4 per cent at 3,500 p.s.i.g. have been obtained.

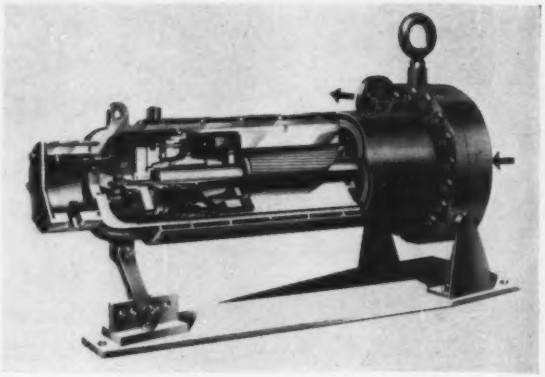
Manufacture of the liquefier has been made possible by parallel developments in production techniques which, to provide the required cleanliness for assembly, are approaching a surgical standard. In addition, means had to be found to produce dry air free from impurities, in particular carbon dioxide, which solidifies in the orifice and causes complete blockage.

This simple unit, which is based on a design by the Royal Radar Establishment, appears to have an unlimited future in a multitude of applications.

Gas-lubricated Pumps and Circulators

Though not of immediate significance in the aeronautical field, Bristol Siddeley were showing a range of gas bearing pumps and compressors. These have been developed in co-operation with the Atomic Energy Commission, primarily for use in research reactors and atomic power plants.

Many design problems had to be overcome in the attempt to provide suitable pumps which could handle the heat transfer media, gas or liquid metal, in the reactor's closed-circuit system. The media are normally under pressure, at high temperature and probably dangerously radioactive. A high degree of chemical purity with no contamination must be maintained. Mechanical seals found in normal pumps cannot be relied upon to meet these arduous conditions.



Gas bearing compressor by Bristol Siddeley.

In addition, common lubricants under irradiation tend to break down.

The solution has been to use gas-lubricated bearings. This has made possible the design of pumps and circulators which can be assembled clean and dry and installed completely sealed from the atmosphere.

Though the theory of the gas bearing is not new, it required the urgency of an atomic energy programme to provide the incentive to overcome the practical difficulties associated with their manufacture. Clearance between shaft and bearing is of the order of 0·0005 in. per in. of diameter. Problems of expansion, standards of roundness and straightness, and of flatness in the case of thrust bearings, soon play havoc with such tolerances.

Of the two types of gas bearing, hydrostatic (pressurised) and hydrodynamic (self-acting), Bristol Siddeley units use the latter. In this system the shaft rests on the sleeve while the machine is at rest. Almost immediately upon rotation the shaft draws a film of gas between the journal and the bearing to act as a lubricant. Thrust bearings are of a viscosity groove type which have a number of shallow spiral grooves cut into their faces. These run parallel with a stationary plate and generate a film of lubricating gas between them.

In contrast to normal lubricants, whose viscosity and thus load-bearing capacity decreases with rise in temperature, gas viscosities increase with temperature, providing a more efficient bearing under these conditions. Once the gas film has been established there is no metallic contact between the shaft and bearing, and no wear should occur. This has been amply demonstrated by units which have run continuously for a number of years, and which, upon stripping down, have shown no measurable wear.

The pumps are mounted vertically, with the impeller immersed in the liquid being pumped. The body of the pump is filled with an inert gas which serves to lubricate the bearings. The circulators or compressors can be mounted in any position, and are lubricated by the gas which is being circulated.

At present the range of circulators contains units from fractional to 120 h.p., capable of operating at up to 650 deg. C., while the pumps vary from fractional to 30 h.p. and operate up to 700 deg. C.

Though designed for the nuclear industry, future uses of these units extend into many fields. Perhaps the most interesting of these is astronautics, where the pumps may be applied to the problems of pumping rocket propellants and fluids without risk of contamination, and for indefinite periods without maintenance.

designer's notebook

PROBLEMS IN DESIGN

Problem No. 10 (August): In a special-purpose machine, driven by an integral horsepower motor, it was found necessary to incorporate, on the input shaft, a torque tripping device which would disengage the motor when a jam occurred caused by oversize workpieces being fed into the machine. Such a device was installed, but was found to be ineffective, as it operated on starting. The inertia of the rotating elements of the machine had been ignored.

Devise a simple torque tripping device that will not become sensitive to torque overload until motor and machine have attained about two-thirds of the normal running speed of 1,500 r.p.m. The device should provide for shaft disengagement by mechanical means, followed by automatic switching off of the motor.

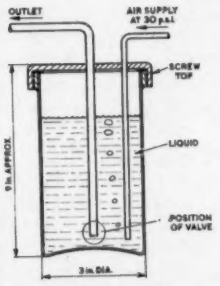
The nature of the above problem requires that the mechanism to solve it must incorporate two elements—a speed-sensitive device and a torque-sensitive device. These two devices must be interdependent in their action, the mechanism becoming more torque sensitive at around 1,000-1,500 r.p.m. It is possible for an induction motor to run in the overloaded condition without any obvious effect on its r.p.m. Only a wattmeter in the motor circuit can reveal overload at once; obvious overheating comes later. The problem is to cater for sudden gross overloads when the machine is running and thus in, say, a woodworking machine, preserve a cutter from breaking or safeguard the operator. A simple torque overload clutch can be devised easily. The difficult part of the above problem lies in providing, in a simple mechanical form, for non-operation of the torque-trip as the motor runs up to speed, i.e., while it is overcoming the inertia of the machine. It is assumed that the motor specified can cater for the momentary overload. Torque transmission in the entry by **D. C. Wood** is via two pins, one on each side of a plate mounted on the input shaft. The pins, which are fitted with bushes as an anti-friction measure, transmit torque via two drive links which are spring constrained against them. The perspective sketch shows the design of the links, and it will be seen that each link is provided with an enlarged portion which, under centrifugal action, tends to diminish the spring force resisting the driving torque. When torque becomes excessive, the two links are forced outwards and apart by the driving pins until a corner of each drive link emerges through a slot in the drive link housing and operates the motor switch. This solution is ingenious, but could possibly be improved so as to avoid a series of gradually increasing percussions against the switch operating lever. The links might be arranged to toggle outwards, with a manual re-set.

A. K. Clyde's entry is more in the nature of a diagrammatic layout and for this reason it a little difficult to understand. It contains, however, a third provision, i.e., for excessive load on starting, which can override the centrifugal device, and is therefore worth studying carefully. It would appear best suited to incorporation within a V belt drive pulley overhung on the motor shaft, rather than for interposing between two shafts. Input is from member (1), which carries a series of dog teeth engaging with an axially floating member (2). This member in turn drives a member (3) by a number of pins (4). A number of small springs (7) keep these two members apart. The ball member (3) carries a number of ball bearings which engage an equal number of radial slots with inclined sides in the output member (8). In order to maintain drive, a pressure plate (9) is loaded by a number of suitable springs (10) (rather curiously shown) on the loading member (11). The torque at which the balls slide out of the slots is governed by the total pressure of the springs (10).

To compensate for starting torque, a centrifugal mass (12) is mounted on the spring loading member. This mass, until moved outwards, engages with the edge of the pressure plate (11). It is capable of a slight radial movement due to centrifugal force, and is also able to make a slight axial movement, restrained by spring (13).

During starting, the output torque is determined by the springs (10) on the spring member (11), plus the axial spring (13) force on the centrifugal mass (12). This torque can be set to any suitable ratio of the running torque by variation of the centrifugal mass spring (13). If, however, a serious overload occurs during starting, the mass can move axially and allow the mechanism to disconnect.

When the drive disconnects, the ball member (13) moves axially to the right (see bottom half of sketch) and so operates the microswitch. During this movement the small springs (7) between the ball member (3) and the floating dog member (2) are compressed, and as the balls ride out on to the flat portion of the output member (8), the driven torque is reduced and these preloaded springs (7) move the floating member axially and disengage the dogs. Further circular movement of the output and ball members is restrained by suitable stops (not shown), so that the motor remains completely disconnected from the load.

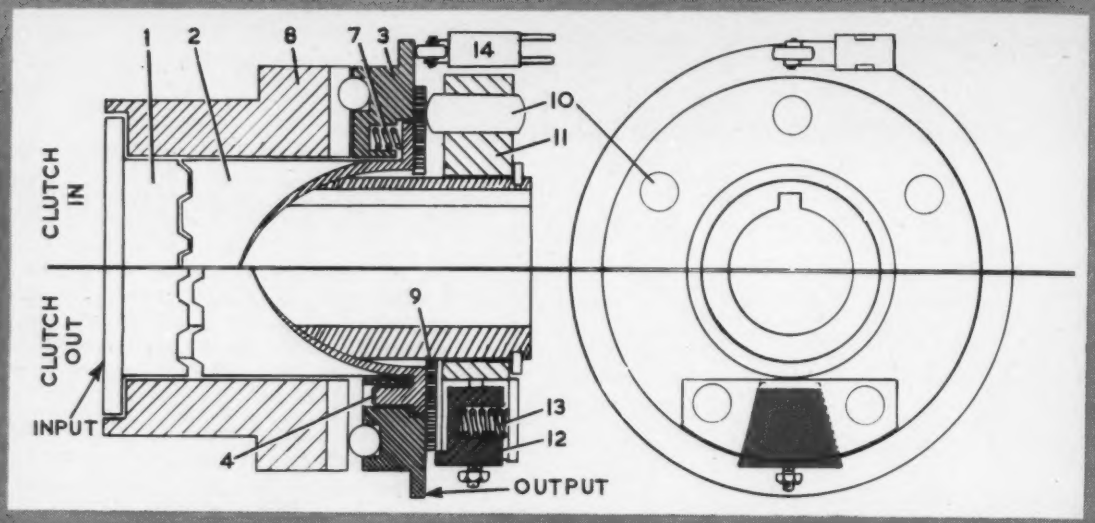


PROBLEMS IN DESIGN

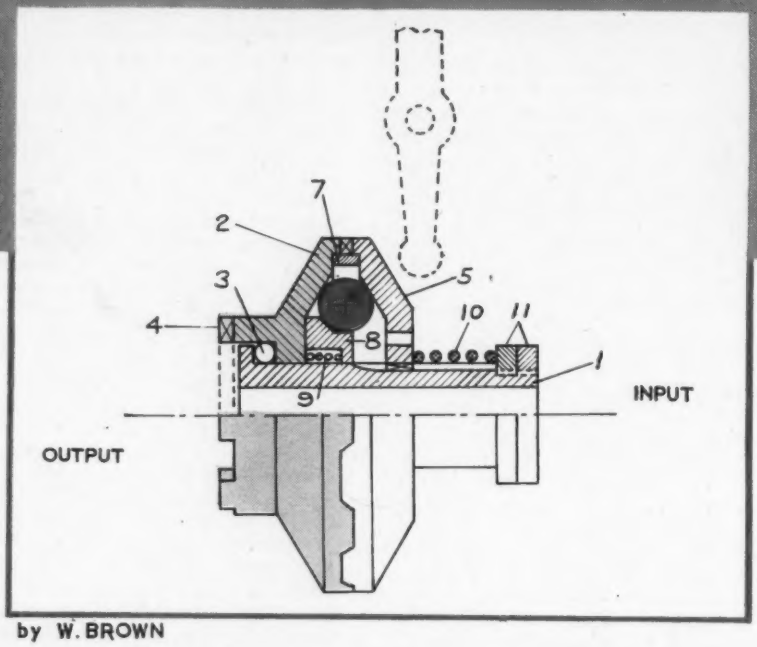
Here is this month's problem

A piece of medical apparatus embodies a liquid container (shown diagrammatically) which is pressurised with air at 30 p.s.i. Both the inlet pipe from the air supply and the outlet pipe for carrying the liquid are of stainless steel. The problem is to design a valve to enable the liquid to be drawn off at will. Since the liquid is a slurry, which is liable to dry and set into a hard abrasive solid, no ordinary on-off gate valve can be used; the entire bore of the pipe, including the flexible portion to the instrument, must remain unconstricted and smooth. It is necessary to incorporate a valve, operated either by a solenoid air valve or by a mechanical air valve controlled remotely by Bowden cable, which would: (a) open the end of the outlet pipe under the liquid, and (b) simultaneously allow a small flow of air through the liquid to keep the slurry in suspension while the valve is open. As the container has to be removed for refilling, no great modification is permissible. The screw top, however, can be redesigned as a casting to incorporate the operating device.

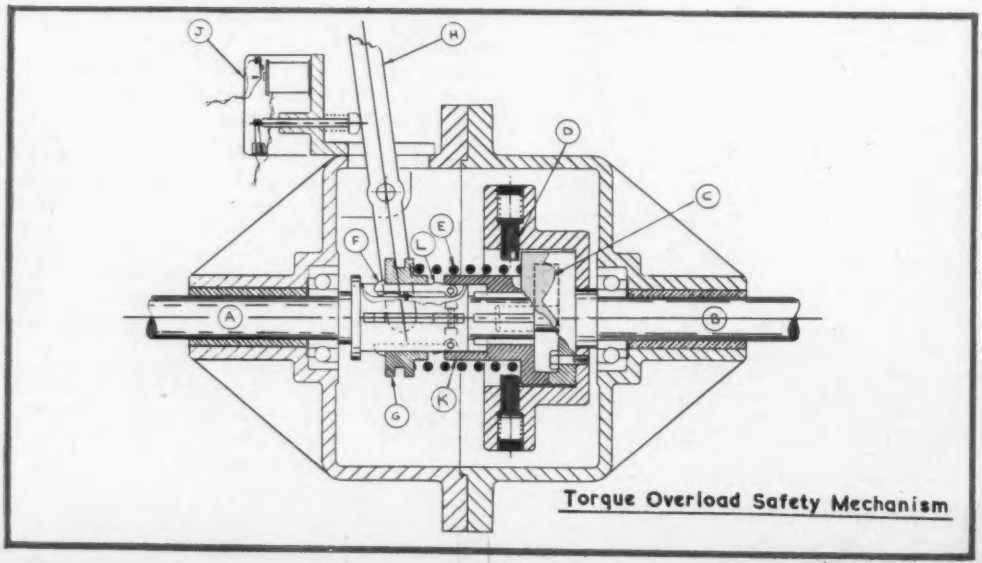
Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12×12 in., please!), to the Editor, "Problems in Design No. 13 (November)". Closing date December 12.



by A.K. CLYDE



by W. BROWN



Torque Overload Safety Mechanism

by A.E. SMITH

A. K. Clyde

This clutch mechanism includes provision for over-riding the centrifugal device in the event of excessive load on starting.

W. Brown

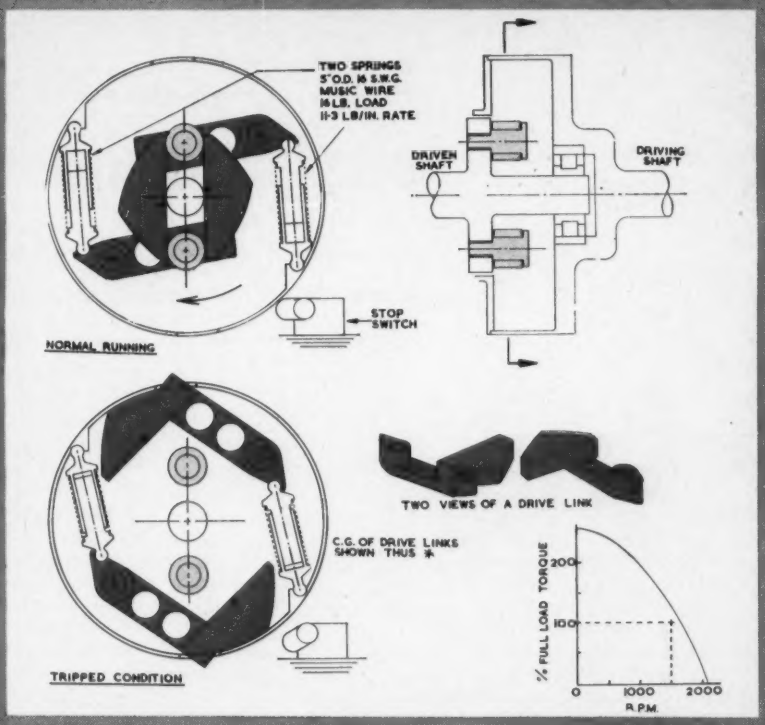
A simple design in which the main spring and clutch just carry the stall torque of the motor.

A. E. Smith

A more elaborate solution incorporating an electro-mechanical re-set for manual operation.

D. C. Wood

A torque-sensitive clutch in which the torque transmission is via pins and drive links acting against springs.



by D. C. WOOD

The entry from **W. Brown** we considered to be particularly neat and simple. A sleeve (1) is keyed to the motor shaft. A two-plate slant-face overload clutch is mounted on this sleeve. Plate (2) is provided with a ball race (3) and dogs (4) to drive the machine. Plate (5) is splined to sleeve (1). The two plates have internal conical faces within which lies a row of balls (6) and a loose ring (7). A sleeve (8) with a light spring (9) lies within the balls. The main spring is secured by adjustable lock rings (11).

The main spring and clutch are designed to just carry the stall torque of the motor. After starting, the axial component of the centrifugal force acting on the balls progressively reduces the main spring load until, at running speed, the clutch just carries the required running torque plus a safety margin. Any increased resistance causes the clutch to rise and permits the balls to move outwards. Their increased centrifugal force, plus the axial clutch thrust, opens the clutch fully, the balls moving out to ring (7) and allowing the sleeve (8) to move under the balls, so maintaining the clutch in the disengaged position. A microswitch lever is operated by plate (5). The clutch is re-set by moving the sleeve (8) to the left via the holes in plate (5).

This solution has the advantages of simplicity and ease of manufacture, the method of adjustment by locking rings being very simple. It would be necessary to ensure that the axial force exerted by spring (9) did not have any appreciable effect on that of spring (10).

Although considerably more elaborate, **A. E. Smith's** solution represents a complete solution to the problem, and is well engineered. It is provided with a simple electro-mechanical re-set for manual operation. Unlike the foregoing entries, the clutch is prevented from disengaging under excessive loads on starting.

The drive is transmitted to the driven shaft (A) through a dog clutch (C) with teeth so formed that increasing torque will displace the driven part of clutch (K) along the splined part of shaft (A). The clutch is held together by spring (E) backing up to collar (G), the spring being designed to hold the clutch in full engagement for normal running torque loads. Collar (G) is held in position by four pawls set in the driven shaft, which are lightly spring loaded. The collar contains a groove for pin location of the forked re-set lever (H). Attached to the driving shaft (B) is a small flywheel containing four spring-loaded pins (D), designed to compress the springs centrifugally at about two-thirds normal running speed. The pins locate behind the clutch, preventing clutch disengagement when the mechanism is at rest. The whole is totally enclosed in a cylindrical, split case with thrust races and plain bearings to take any side thrust of shaft. Feet can be cast on the body for mounting purposes. This is a general-purpose mechanism, but could be adapted quite easily for mounting direct on the motor casing by a simple alteration to the casting.

It can be seen from the diagram that on starting up the motor the excess starting torque will cause the clutch to partially disengage and jam up against the centrifugal pins. As normal running speed is approached the torque load decreases and allows the clutch to move back until fully engaged, the centrifugal pins now being free to move out. Should a jam now occur while running at normal speed, the dog clutch will move out and in doing so press down the pawls by means of the ramps (L), thus releasing the spring retaining collar. The spring forces back the collar until all the compression is released and shaft disengagement is effected. In the current cut-off box (J) a pair of contacts are held together by a spring-loaded plunger in contact with the re-set lever. These contacts make a circuit for a low-voltage solenoid which, in turn, holds in the main current contacts. When shaft disengagement takes place the re-set lever moves forward, allowing the spring-loaded plunger to break the solenoid circuit, which causes the main current contacts to break, thus cutting off the motor.

DIESEL ENGINES UP TO 300 B.H.P.

The unusual adaptability of the diesel engine enables the designer to meet the specific requirements of various industries. The following article presents features of diesels which are obtainable in the U.K.

THE first demonstration of a diesel engine took place in Munich in 1898, and heralded an era in which the compression ignition engine was to grow from a heavy and slow-running type of prime mover to a high-speed engine directly challenging some applications of the petrol engine. Diesel engines today are found not only in industrial applications but in private motor cars, where they often show a fuel economy over petrol engines and at the same time give an equal performance. Small pleasure-type marine craft provide increasing applications for diesel engines, and the latest development is the outboard diesel.

An increasing tendency is one directed towards the air-cooled diesel, where the absence of water is an added advantage for industrial applications. A double-decker bus fitted with an air-cooled diesel has been operating in the U.K. for some years, and shows an improved running economy as compared with the original water-cooled engine.

Because of the widespread use of liquid fuel it is often assumed that the diesel engine is so named because of the use of these fuels. This is not so, as pulverised coal, natural gas and sewage gas were used in early experiments and many engines today are multi-fuel or dual-fuel engines. The latter definition is applicable to engines which can operate, without alteration, on both liquid oil fuel and a combination of liquid and gas fuels. Multi-fuel engines, as the name implies, can operate with the minimum of alteration on fuels such as diesel oil, high-octane petrol, kerosene-based fuels and jet fuel.

In the four-stroke diesel engine, air is drawn on the suction stroke of the piston through valves and compressed on the return stroke, at which point the fuel is sprayed into the combustion chamber, the heat of the compressed air being sufficient to cause ignition (see Fig. 1). The third, or power stroke thus occurs, the cylinder being exhausted on the fourth stroke, and the flow of gas controlled by an exhaust valve. In the two-stroke diesel engine the air is directed into the cylinder through ports uncovered by the piston at the bottom end of its travel. This air has previously been compressed either by an external blower or in the engine crankcase by the previous downward stroke of the piston. The air in the cylinder is further compressed by the upward stroke of the piston, at which point fuel is sprayed into the combustion chamber, the heat of the air being sufficient to cause ignition, thus giving a power stroke. At the end of the power stroke, exhaust ports are uncovered by the piston to allow the escape of the exhaust gas, while at the same time a fresh charge of air enters from other ports (see Fig. 2).

In the uniflow system a blower is used, the air being admitted through ports in the lower part of the cylinder walls, and the exhaust controlled by a valve (see Fig. 3).

The Kadency system of scavenging is one where the energy of the burnt gases is utilised for evacuating the cylinder, the outstanding feature being the quick opening of the exhaust valves. The success of this system depends on the relationship of the inlet porting to the exhaust valve timing.

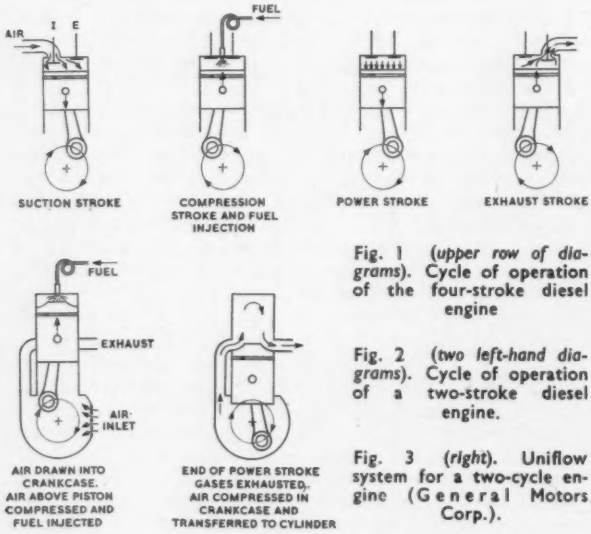
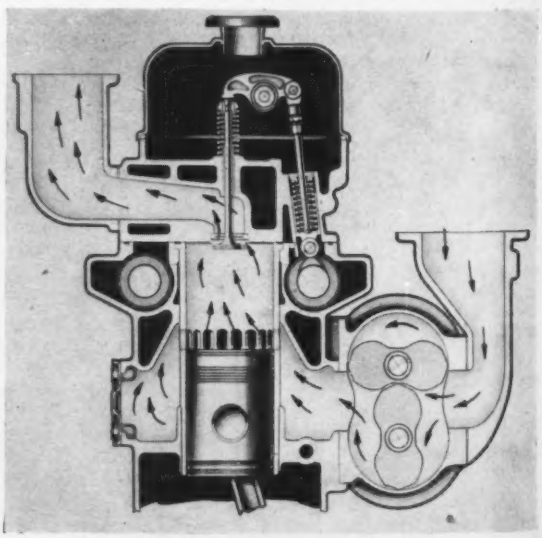


Fig. 1 (*upper row of diagrams*). Cycle of operation of the four-stroke diesel engine

Fig. 2 (*two left-hand diagrams*). Cycle of operation of a two-stroke diesel engine.

Fig. 3 (*right*). Uniflow system for a two-cycle engine (General Motors Corp.).



Pressure Charging

A blower or supercharger can be used on both four-stroke and two-stroke engines, and may be driven either mechanically from the engine or by a directly coupled exhaust-gas-driven turbine. The combination of turbine and blower is referred to as a turbocharger (see Fig. 4). By increasing the amount of air in the cylinders and therefore allowing more fuel to be burnt, the output of the engine can be increased. Because the air compressed by the turbocharger or supercharger increases in temperature, and because warm air is less dense than cool air at the same pressure, an aftercooler is often used to cool the air flowing from the turbocharger to engine cylinders in order to get more oxygen into cylinders.

Pressure charging four-stroke engines became necessary when the two-stroke engine was popularised because only better utilisation of the swept volume and an increase in the power-weight ratio (specific weight) prevented the former from being displaced by the latter in certain applications.

In the earlier type of pressure-charged diesel engine the supercharger was driven by an electric motor; later, compressors were used which were driven from the engine. Alternatively, the underside of the engine piston was used as an air pump. All these charging systems entail a certain amount of extra power for compressing the air. With turbocharging, however, no additional power is necessary for compressing the air, because part of the energy contained in the exhaust gases of the diesel engine is utilised by the gas turbine driving the blower. Thus, exhaust gas turbocharging is the most efficient method of pressure charging, and this is one of the principal reasons why this system has been more widely adopted than all the others.

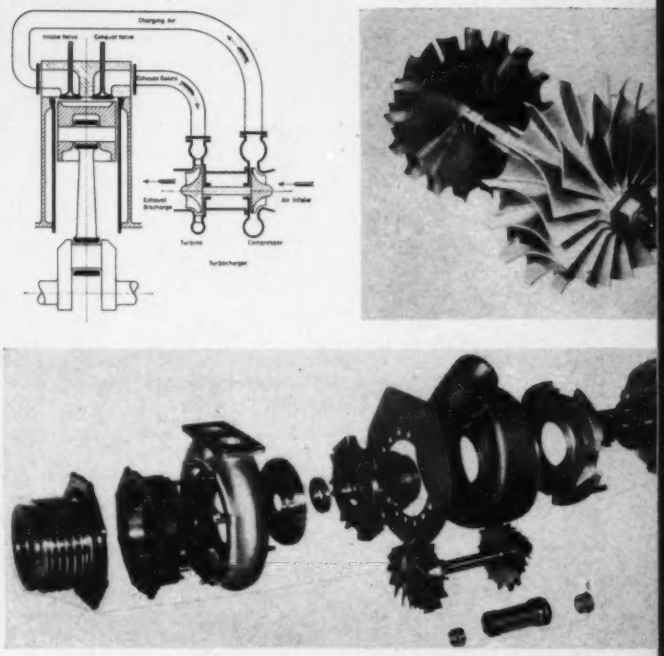


Fig. 4. Component parts of the Buchi turbocharger, with rotor assembly (*top right*) and (*top left*) principle of operation.

Combustion Chambers

One technical aspect which characterises diesel engines is the design of the combustion chamber. Although there are several types, the object of all designs is to ensure that the air and fuel are suitably mixed, in order that progressive and even burning of the fuel takes place. In some designs the underside of the inlet valve has a projection, known as a mask, intended to promote swirl or turbulence. Other devices connected with combustion chambers include starting devices such as glow plugs and heaters which assist starting under varying climatic conditions.

Many types of combustion chamber have been designed so that the injected fuel can be distributed in such a way that maximum utilisation of the oxygen will be possible. The importance of completely burning all the fuel injected may be appreciated when it is realised that the output, and thus the cost, depends entirely upon this. The open combustion chamber, as may be seen from Fig. 5, can be located either in the cylinder head or in the crown of the piston, and various forms have been used in order to obtain better fuel and air distribution. For the same reason, masked inlet valves (see Fig. 12) are sometimes used.

The pre-combustion chamber is one in which partial combustion takes place prior to the entry of the gas into the main chamber, where the combustion process is continued. All of the fuel charge is injected into the pre-combustion chamber, an example of which is shown in Fig. 6. The high pressure created during initial combustion drives the remainder of the fuel into the main chamber, where the additional oxygen enables the process to continue. The throat or orifice between the pre-combustion chamber and the main chamber is designed specifically to ensure the correct distribution of the mixture. The pre-combustion chamber is normally uncooled, and the heat retained from the previous combustion plays an important part in initiating the next.

A further example of a pre-combustion chamber (shown in Fig. 7) is known as the Ricardo whirlpool. In this particular example the lower part is made of stainless steel.

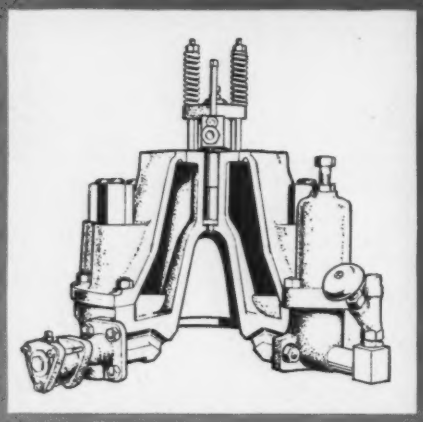
The swirl combustion chamber, sometimes called the turbulence chamber, is a separate cavity into which the charge is transferred by the compression stroke and given a rotational movement in the process. When the fuel charge is injected into this mass of air, combustion commences, and the resulting high pressures force the partially burned fuel into the cylinder where it is added to the existing air trapped in the piston clearance space. An example of a swirl chamber is shown in Fig. 8.

A different type of swirl chamber is shown in Fig. 10. In this case the cavity is contained within the crown of the piston. Another means for promoting swirl is shown in Fig. 9, where it can be seen that the air is given a rotational movement by virtue of the geometry of the inlet duct.

The air cell combustion chamber consists of a cavity connected to the cylinder by a restricted orifice. The cavity itself is partially divided into two compartments, and the openings of each are opposite and in line with the injector nozzle (see Fig. 11). The fuel is injected across the engine cylinder into the air cell. In some designs no combustion takes place in the cell, while in others an appreciable amount of the combustion originates within this cell.

The Pannon design represents a novel type of simple combustion process for diesel engines, and operates at a temperature above that normally attained. The combustion process takes place in an uncooled part of the cylinder head, thus utilising the largest amount possible of heat for rapid combustion (see Fig. 14). The spherical combustion chamber, into which the whole of the atomised fuel is injected, allows the fuel to be spread out on the uncooled hot surface by the incoming air flow. With this form of combustion process a small compression ratio of 1:6 may be employed, since the propagation and ignition of the mixture is caused by the heat of the uncooled wall.

An interesting means of improving the breathing capacity and combustion efficiency over a wide range of load and



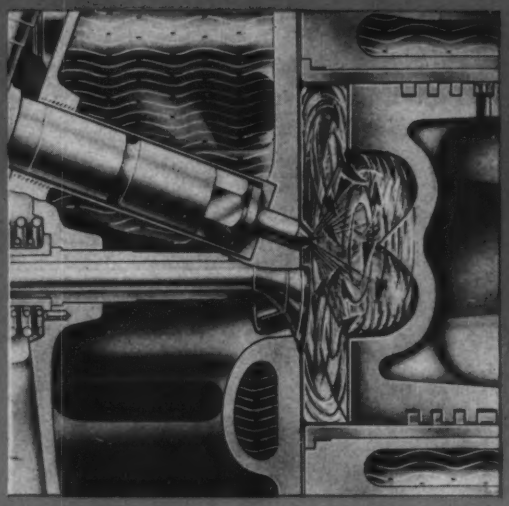


Fig. 5 (*above*). Open-type combustion chamber in cylinder head (H. Widdop & Co. Ltd.); (*right*) toroidal cavity in piston crown (A.E.C. Ltd.).

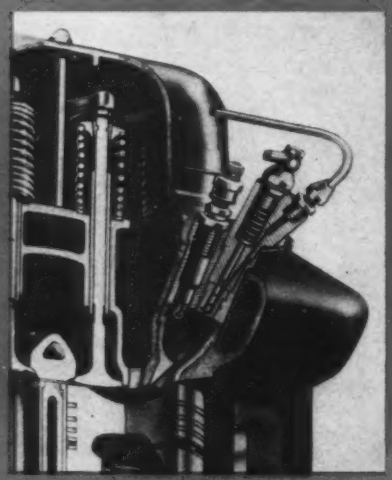


Fig. 6. Pre-combustion chamber with indirect injection. Note the glow plug for instant starting (International Harvester Co.).

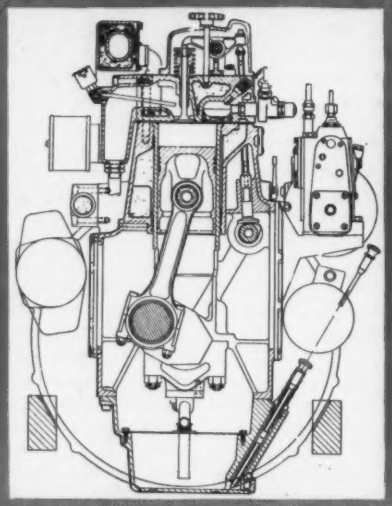


Fig. 7. Alfa Craig engine with Ricardo Whirlpool combustion chamber.

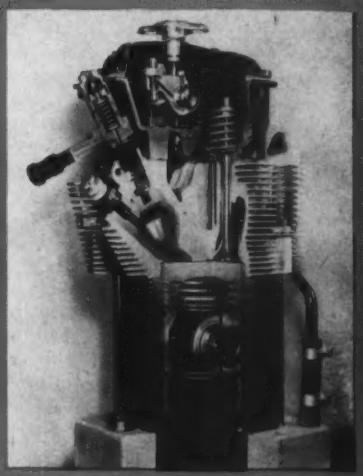
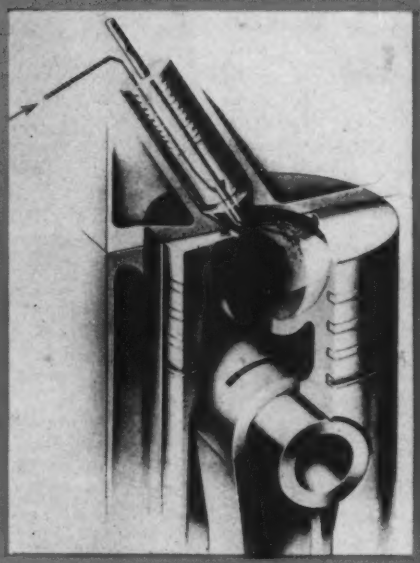


Fig. 8. Sectional view of the cylinder used in the Deutz air-cooled engine, showing the swirl-type pre-combustion chamber.



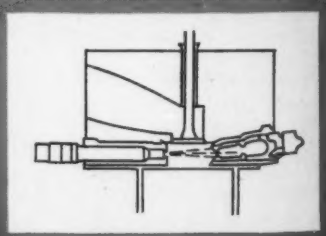


Fig. 9 (*far left*). Air swirl in the cylinder of the M.A.N. engine during the suction stroke.

Fig. 10 (*left*). M.A.N. spherical combustion chamber in piston crown.

Fig. 11 (*above*). Air cell type of combustion chamber

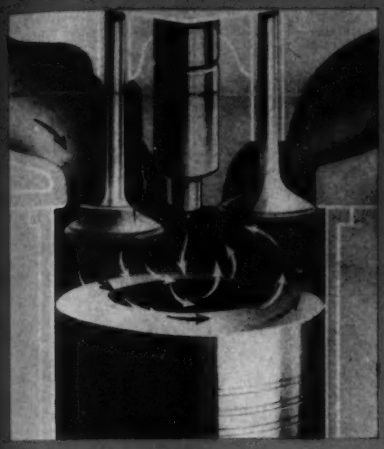


Fig. 12. Controlled air swirl produced by inlet valve shroud or mask (British Motor Corp.).

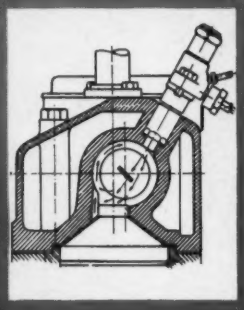


Fig. 13. Clerestory type of combustion chamber using horizontally-opposed valves.

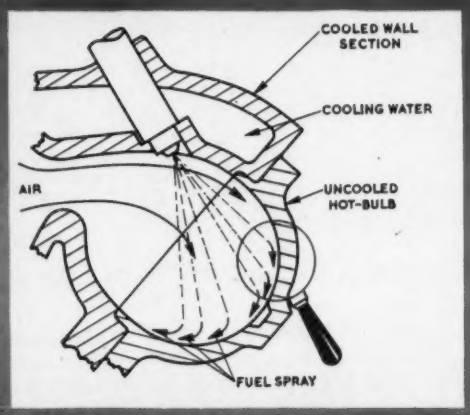
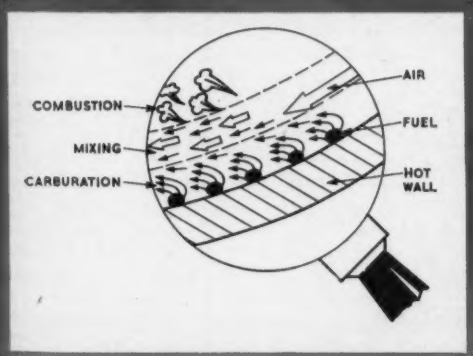


Fig. 14 (above). Pannon spherical combustion chamber, with (below) enlarged view showing combustion process.



speed in small and medium size high-speed diesel engines is the Buchi telescope valve system, which consists of two valves co-axially arranged, one within the other. One of these valves admits the charge and the other is used for discharging the exhaust gas. Fig. 15 indicates the path of the incoming air, ample scavenging being a primary design factor, as with a suitable valve overlap it is possible for both valves to remain open during the scavenging period. The advantage of this valve system as compared to conventional engines is the much smaller surface of the compression space in comparison with the swept cylinder volume, and the formation of an intensive fresh air vortex by the use of a spiral admission duct within the cylinder head, to adequately mix the fuel. The concentric arrangement of the inlet and exhaust valves allows an ample dimensioning of the passages for the gas. In this system the inlet valve is increased in weight, but the effect of this is of lesser importance, since the inertia loads on inlet valves are considerably less than those imposed on the exhaust valves.

Cylinder Liners

It is usual for the cylinders in a diesel engine to be made from cast iron, and to be fitted with a liner which can be replaced. Two types of liner are available, one being a dry liner fitted within the bore of the cylinder block, and the other a wet type of liner which registers with the cylinder block on only the upper and lower parts of its length. Some form of sealing is used at the lower end to prevent the ingress of water, the most usual scheme being a plastic seal which also permits expansion to take place (see Fig. 16). A metallic gasket is often used at the upper end. Various materials can be used for the liners, and it is a matter of preference as to the type selected. To prevent corrosion of wet-type liners many manufacturers employ a form of protection, such as a ceramic coating, on the outer surface.

Selection

The engine for a specific application is not easily chosen, since there are many conflicting requirements, and these are unlikely to be found in any one manufacturer's engine. To assist in making a choice, the tabular data following this article have been compiled with some degree of uniformity regarding the power output. Manufacturers often find it convenient to express the ratings of their engines in different ways, but as far as practicable the power ratings expressed in the tables are to BS 649: 1958,* in which the BS rating is the net output which the engine is capable of giving continuously, under given conditions of barometric pressure, humidity and inlet temperature, and with a fuel corresponding to an approved specification. An overload of 10 per cent of the BS rating at the same speed is specified for one hour in any period of 12 hours' consecutive running. Other BS specifications are BS 1744, tests for agricultural tractors; BS 2800, tests for industrial crawler and wheeled tractors; and BS 2943, diesel engines for rail traction.

In certain cases an automotive rating is given, which is the maximum power which can be obtained and used for intermittent periods. Twelve- and twenty-four-hour ratings are also specified by certain manufacturers. For marine engines the power quoted is often that given at the propeller shaft, and is generally the maximum continuous, since marine engines operate for long periods at one speed, and where torque demands are more or less constant. Thus, in many cases torque values have been omitted, but these may be obtained from the manufacturers for any proposed installation. In using the following tables it should be remembered that a complete range of engines from a particular manufacturer may not be shown, and it is also

* *An earlier specification, BS 649: 1949, quoted the rating over a period ratings do conform to the latest specification, i.e. BS 649: 1958.*

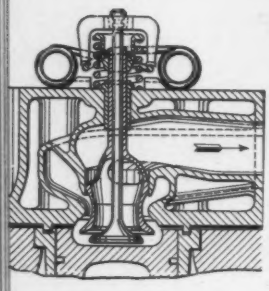


Fig. 15. Buchi telescopic valve system.

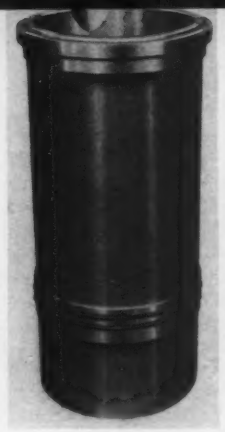


Fig. 16. Typical wet type cylinder liner (W. H. Allen Sons & Co. Ltd.).

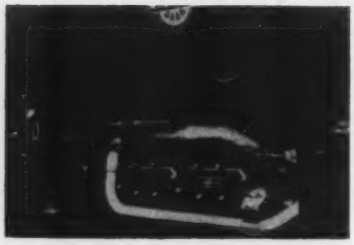


Fig. 17. B.U.T. type RE901 diesel in British Railways' power car.

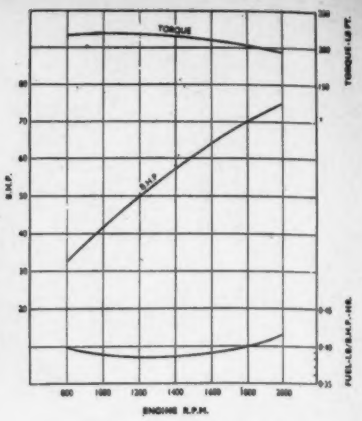


Fig. 18. Typical power curves for a diesel engine.

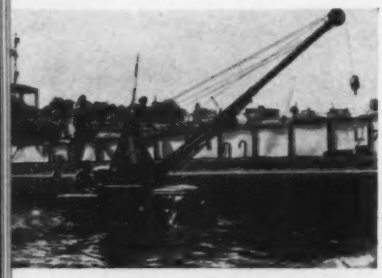


Fig. 19. Deutz air-cooled diesel fitted to a crawler tractor.

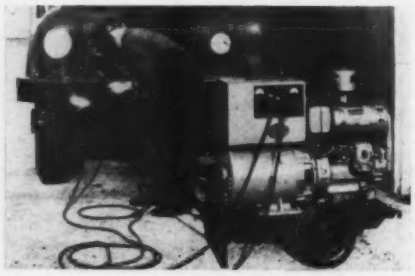


Fig. 20. Petter diesel installed in an Ashton-Young welding outfit.

Fig. 21. Fifty-h.p. diesel fitted to a skid shovel (International Harvester Co.).

possible that certain manufacturers are not included; this is due only to the desire to limit the engines in this survey to an arbitrary figure of approximately 300 b.h.p. It should also be remembered that the tables are intended only as a guide for selection, and that for greater detail reference should always be made to the relevant manufacturers.

Typical power curves are shown in Fig. 18, the torque curve varying from being comparatively flat over a wide range of speeds, to one which has a peak at one particular speed. The horsepower increases with speed over a certain speed range, and then starts to drop fairly rapidly at some well-defined point. The fuel consumption varies according to engine duty and type, and whether it is normally aspirated; it is usually quoted as gallons, pints or lb. per b.h.p. per hr. (a typical curve is shown in Fig. 18).

BIBLIOGRAPHY

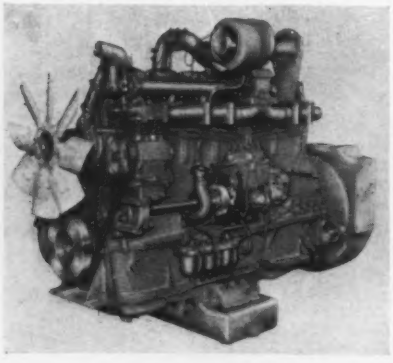
The Diesel Engine (The Macmillan Co.).
British High-speed Diesels (Temple Press).
World Directory of Manufacturers (Temple Press).
The Motor Boat and Yachting Manual (16th edition) (Temple Press).

We gratefully acknowledge the assistance of diesel manufacturers in the compilation of the following data, and every effort has been made to ensure the accuracy of the information. It may be assumed that, unless otherwise indicated, the engines described are water-cooled.

PRINCIPAL MANUFACTURERS AND SUPPLIERS OF DIESEL ENGINES UP TO 300 B.H.P.

A.E.C. Ltd.

The engines of this company are basically 4- and 6-cylinder vertical in-line engines which for certain models have been modified to a flat horizontal engine for automotive applications. In the entire A.E.C. range, overhead valves operated by pushrods are used, the camshaft being gear driven. All the engines are of the four-stroke cycle employing direct injection and wet cylinder liners. The engines are mainly used for automotive and industrial work; for the latter, engines are available as a unit complete with radiator.



AV 1100 Industrial.

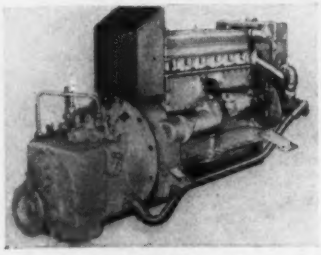
Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
AV 275	4	4·5	52/1,800	64/2,000	193/1,300	1,150
AV 312	4	5·1	60/1,800	75/2,000	218/1,200	1,150
						1,000*
AV 410 (Industrial)	6	6·75	79/1,800	112/2,200	285/1,300	1,650
(Automotive) V						1,285*
(Automotive) H						1,405*
AV 470 (Industrial)	6	7·69	90/1,800	126/2,200	335/1,200	1,650
(Automotive) V						1,285*
(Automotive) H						1,405*
AVT 470 (turbo-charged)	6	7·69	110/1,800	150/2,200	427/1,200	1,720
AV 590	6	9·64	109/1,800	139/2,000	430/1,100	1,825
						1,700*
AV 690	6	11·31	132/1,800	168/2,000	505/1,200	1,825
						1,700*
AVT 690 (turbo-charged)	6	11·31	170/1,800	220/2,000	674/1,200	1,900
AV 1100 (Industrial)	6	17·89	228/1,800	275/1,900	890/1,300	3,550
(Automotive) V						3,285*
(Automotive) H						3,405*
AVT 1100 (turbo-charged)	6	17·89	285/1,800	360/1,900	1,180/1,200	3,650

V = Vertical engine.
H = Horizontal engine.
Weights given are for industrial engines. Automotive engine weights are marked thus—*.

Ajax Marine Engines

Although primarily for marine purposes, these engines may be used for industrial applications. All engines work on the four-stroke principle, the three smaller engines being 4-cylinder models, the remainder 6-cylinder models. Except for the Aries, engines employ direct injection and overhead valves operated by pushrods from a gear-driven camshaft; Aries uses a chain-driven camshaft and a combustion chamber of the Ricardo Comet V type. Except for the Argosy and Argonaut, which employ wet cylinder liners, the remaining engines use dry liners.

In most cases these units are modified versions of Leyland and Albion standard engines, the arrangements being as follows: Amazon—Leyland 350; Apollo, Atalanta—Leyland diesel characteristics; Argosy—Leyland/Albion EN 900; Argonaut—Leyland/Albion EN 900; Albacore—Albion ;and Albatross—Albion.



Amazon Marine.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight incl. gearbox (lb.)
Aries	4	2·3	40/2,200	50/3,000	97/2,000	750
Albacore	4	3·84	—	—	—	1,200
Albatross	4	4·9	—	—	—	1,792
Amazon	6	5·75	69/1,800	110/2,200	260/1,600	—
Apollo	6	9·8	110/1,800	135/1,800	420/1,200	3160 to 3,580*
Atalanta	6	11·1	129/1,800	155/1,800	490/ 800	3,160 to 3,580*
Argosy	6	15·2	170/1,600	215/1,700	710/1,150	5,040
Argonaut (supercharged version of Argosy)	6	15·2	207/1,600	275/1,800	800/1,200	—

*Depending on type of gearbox.

Ailsa Craig Ltd.

The stationary-type engines have been developed from the marine engines and have the inherent advantages of marine accessibility and reliability. They are water-cooled and employ wet liners, the cylinder head being designed to accommodate an easy cold start pre-combustion chamber into which the fuel is injected, the overhead valves being operated by pushrods from a side gear-driven camshaft. The single- and twin-cylinder models RL were previously RF prior to improvements which include pre-finished connecting rod bearings and a full-flow Autoklean oil filter. The RK 3, 4 and 6 engines replace their RF counterparts and include similar improvements as well as standard S.A.E. bell housings for welding, pumping and generator sets.

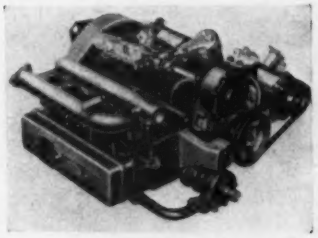
Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
RL 1	1	1·203	10/1,200	11/1,200	45/1,050	672
RLS 1	1	1·203	10/1,200	11·5/1,350	43/1,350	878
RL 2	2	2·406	20/1,200	22/1,200	88/1,100	881
RLS 2	2	2·406	20/1,200	22·5/1,350	87/1,350	1,008
RLSF 2	2	2·406	21/1,500	23/1,500	83/1,500	1,008
RK 3	3	3·609	35/1,500	38·5/1,500	132/1,100	1,372
RK 4	4	4·812	46/1,500	50·5/1,500	175/1,150	1,540
RK 6	6	7·218	70/1,500	77/1,500	265/1,100	1,812
RA 6	6	9·588	100/1,500	110/1,500	350/1,100	2,352

Albion Motors Ltd.

The two engines marketed by this company are for automatic application and are fitted to the Albion Claymore and Albion Chieftain. Both vertical and horizontal engines are of the direct injection type and are fitted with dry-type cylinder liners. Overhead valves are operated from a gear-driven camshaft.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./ r.p.m.)	Dry weight (lb.)
EN 335 (four-stroke) Vertical	4	5·5	—	94/2,200	252/1,250	1,126
EN 250H (four-stroke) Horizontal	4	4·1	—	72/2,200	190/1,300	924

EN 250H Horizontal.



W. H. Allen Sons & Co. Ltd.

The smallest type of unit made by this company is the normally aspirated Type S.12 engine which is available as either 3-, 4-, 5-, 6-, 7- or 8-cylinder models designed to be directly coupled to a generator as a marine auxiliary set. The bore and stroke are 9 in. and 12 in. respectively, and the engine employs wet cylinder liners. Separate detachable cylinder heads are used, the overhead valves being operated by pushrods from a chain-driven camshaft. The outputs from these engines are tabulated below and are designed for constant speed operation.

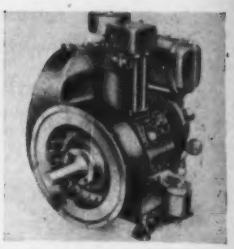
3-cylinder model output is			135 b.h.p.	90 kW. at	600 r.p.m.
			162	108	750
4	,,	,,	180	120	600
			216	144	750
5	,,	,,	225	150	600
			270	180	750
6	,,	,,	270	180	600
			324	216	750
7	,,	,,	315	210	600
			378	252	750
8	,,	,,	360	240	600
			432	288	750

Bamfords Ltd.

In the range of vertical engines produced by this company the accent is on reliability, the engines covering powers from 3½ to 16 b.h.p. The 3½ to 8 b.h.p. models are water-cooled by radiator, tank or hopper, these engines forming part of the Z series of single-cylinder models. The twin-cylinder engines cover the range from 10 to 16 b.h.p. and are either tank or radiator cooled; wet cylinder liners are used for both single- and twin-cylinder models. Engines operate on the four-stroke principle with direct injection, the overhead valves being operated by a single cam. The latest addition is the AC. 1 air-cooled diesel of 19·1 compression ratio, air being supplied from a shrouded flywheel incorporating suitable vanes. Overhead valves operated by pushrods are used and the cylinder barrel is detachable from the crankcase and head.

Type		Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.) (1 hr. rating)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
AC.1 (single-cylinder, air cooled)		7/1,800	7·7/1,800	21·1/1,450	390
Single-cylinder, water-cooled	Z 1	3½/600	3·85/600	32/650	770
	Z 2	4½/600	4·95/600	41/650	812
	Z 2 M	5½/750	6·05/750	41/750	812
	Z 3	7/600	7·7/600	63/650	924
	Z 4	9/700	9·8/700	63/650	924
Twin-cylinder, water-cooled	Z 5	10/650	11/650	91/650	1,183
	Z 6	12/750	13·2/750	91/650	1,183
	Z 7	14/600	15·4/600	124/650	1,344
	Z 8	16/700	17·6/700	124/650	1,344

Bamfords Ltd. (cont.)



AC.1 Air-cooled.

Bellis & Morcom Ltd.

These engines are primarily for generating purposes, both stationary and marine, and are available in powers up to 2,000 b.h.p. The engine powers may be boosted by means of turbo-charging, both with and without after-coolers. Four-stroke principle of operation is employed using direct injection. Overhead valves operated from a chain-driven camshaft are used and wet replaceable cylinder liners are fitted, these being made from nickel-chrome iron. A fuel injection pump is fitted to each cylinder, so that the connecting pipe to the atomiser is as short as possible. The inlet and exhaust valves are carried in individual cages each complete with rocker assembly.

Types (Normally aspirated)	No. of cylinders	Capacity	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.) (1 hr. rating)	Max. torque (lb. ft.) (1 hr. rating)	Dry weight (cwt.)
5 A.L.S.	3	8·5 in. bore × 13 in. stroke	120/600	132/600	1,156	114
	4		160/600	176/600	1,545	145
	5		200/600	220/600	1,930	163
	6		240/600	264/600	2,312	188
	7		280/600	308/600	2,700	201
	8		320/600	352/600	3,090	232
11A/11ALS	3	11·5 in. bore × 15·5/18 in. stroke	225/500-428	247/500-428	2,600/3,040	332/335
	4		300/500-428	330/500-428	3,470/4,050	356/360
	(5-, 6-, 7- and 8-cylinder models range up to 600 b.h.p. (normally aspirated))					
12A	2	12·75 in. bore × 17 in. stroke	150/375	165/375	2,310	293
	3		225/375	248/375	3,470	346
	4		300/375	330/375	4,620	400
	(5-, 6- and 7-cylinder models range up to 525 b.h.p. (normally aspirated))					

Bolinders Co. Ltd.

All of the marine engines listed are fitted with mechanical reverse-reduction gearboxes, but oil-operated gearboxes are offered as an alternative in some cases. With the exception of the MD.1 and MD.4, all the engines are fitted with renewable cylinder liners, and apart from the MD.1 are supplied complete with fresh-water coolers.

Single inlet and exhaust valves are common throughout the whole range, and camshafts are gear-driven. Combustion chambers, with the exception of the MD.4, are of the open type, this model incorporating a pre-combustion chamber.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Penta Diesels						
MD.1	1	0·445	5/2,000	5/2,000	—	285
MD.4	4	1·77	30/2,500	30/2,500	65	510
MD.47	6	4·7	82/2,500	92/2,500	200	1,540
MD.67	6	6·73	103/2,400	115/2,400	290	2,200
MD.96	6	9·6	135/2,200	150/2,200	430	2,650
TIMD.96	6	9·6	185/1,800	205/1,800	595	2,870
Bolinder Diesels						
1051–BR	1	1·12	11·5/1,500	12·7/1,500	44	1,050
1052–BR	2	2·24	25/1,500	27·5/1,500	80	1,325
1113–BR	3	3·78	50·5/2,000	55·5/2,000	145	1,740
1114–BR	4	5·04	67·5/2,000	74·5/2,000	200	2,115

Bolnes (Plenty & Son Ltd.)

These water-cooled engines range in power from 50 b.h.p. for the single-cylinder model to 1,500 b.h.p. for the super-charged 20-cylinder model, the following table listing only those under 300 b.h.p. Designed for industrial applications, marine propulsion and auxiliary units, they are two-stroke uniflow-type engines employing direct injection into the combustion chamber in the crown of the piston, the overhead exhaust valves being operated by pushrods from a chain-driven camshaft. The cylinder liners are of the wet type and are replaceable.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
1-L	1	9·9	50/430	60/430	735/430	5,950
2-L	2	19·8	100/430	120/430	1,470/430	8,150
3-L	3	29·7	150/430	180/430	2,205/430	10,360
4-L	4	39·6	200/430	240/430	2,940/430	12,560
5-L	5	49·5	250/430	300/430	3,675/430	15,000
6-L	6	59·4	300/430	360/430	4,410/430	17,200
(7- and 8-cylinder models of higher b.h.p. also available)						

Bradford Diesel Engine Co. Ltd.

The A series of diesel engines are vertical water-cooled types suitable for industrial applications. They are of the four-stroke cycle with overhead valves and a precombustion chamber with indirect fuel injection. Wet-type cylinder liners are used, and the overhead valves are pushrod operated from a gear-driven camshaft.

Basic type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
1A	1	1·03	6½/1,000	9/1,500	31/1,500	616
2A	2	2·06	13/1,000	18/1,500	63/1,500	868
4A	4	4.12	32/1,200	36/1,500	126/1,500	1,848

Bristol Commercial Vehicles Ltd.

The Bristol BVW engine is a 6-cylinder, direct-injection, overhead-valve, water-cooled model of 8·91 litres capacity. The inlet ports in the cylinder heads are fitted with choke tubes, the function of which is to control the air swirl to promote efficient combustion. Flanged wet liners are of cast iron with twin water sealing rings at the lower end. Camshaft and fuel pump are driven from a steel pinion on the front of the crankshaft through a common idler gear. The maximum governed engine speed is 1,750 r.p.m. and 115 b.h.p. is available at 1,700 r.p.m. with a maximum torque of 380 ft. lb. at 1,200 r.p.m.

British Deutz Ltd.

This company markets an extensive range of horizontal and vertical engines for all purposes. Type MAH is a horizontal, evaporative water-cooled, single-cylinder, high-speed four-stroke engine, employing a wet cylinder liner and a precombustion chamber, the crankshaft being carried in either plain or roller bearings. Overhead valves operated by pushrods are employed, and the camshaft is driven through helical gears. The engines are primarily for stationary or mobile equipment.

The FL. 712 series includes a single-cylinder, twin-, 3-, 4- and 6-cylinder versions, all wearing parts being interchangeable. These vertical engines are air cooled and incorporate a swirl chamber for combustion, the overhead valves being pushrod operated from a gear-driven camshaft. Cooling for the single- and twin-cylinder version is effected by a flywheel blower, the air intake being bolted to the crankcase. Cooling for the other three versions is by means of an axial flow blower, belt driven from the crankshaft. All engines of this series can be used for automotive, industrial or marine applications.

The AL/514/614/714 series of air-cooled diesel engines for industrial use range from a single-cylinder to a 12-cylinder type and employ the swirl chamber combustion principle. All the engines are fitted with oil bath air filters, and starting, in the case of the single- and twin-cylinder engines, is usually by hand. These engines can also be supplied with integral oil cooler for use with torque converters. Electrical or compressed air motor starters are used for the larger engines. Multi-cylinder engines may also be equipped with inertia starters if required, and for most of the models clutches and gearboxes are available to suit specific applications. This series is also available as multi-fuel engines—petrol to crude oil—gas conversion parts are also available. All the engines are equipped with a speed control governor enabling a constant speed to be maintained as the load on the engine varies. The 12-cylinder model can also be supplied with a Buchi type supercharger. These engines are also suitable for automotive or marine use and designated "FL" or "SA" respectively when fitted with variable speed governors.

The 4-cylinder unit is an in-line engine, while the 8- and 12-cylinder units are V types; the 6-cylinder engine can be obtained in either the in-line or V form.

The AM 517 series are water-cooled engines available in 4, 6 and 8 cylinders in line form and are suitable for stationary or marine use. The 8-cylinder unit can also be obtained with a supercharger. The FM 617 is also a water-cooled unit having 6 cylinders in line and designed for automotive use.

The FM 716 series cover a water-cooled engine with 3, 4 and 6 cylinders in an in-line form, the 12-cylinder model being of "V" formation. The 6- and 12-cylinder versions are also available with exhaust-driven turbo-chargers. The "V" form cylinders are at 120°, thus giving a very low height unit particularly suitable for automotive use.

Type	No. of cylinders (V = V formation S/C = supercharged)	Capacity (litres)	Max. continuous rating[1] (b.h.p./r.p.m.)	Max. rating[2] (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Net weight[3] (lb.)
A/F2L 514	2	2·66	28/1,800	32/1,800	104·6/1,100	860–915
A/F3L 514	3	3·99	42/1,800	48/1,800	159/1,200	1,014–1,025
A/F4L 514	4	5·32	56/1,800	85/2,300	223·8/1,200	1,213
A/F6L 514	6	7·98	84/1,800	125/2,300	333·1/1,200	1,610–1,683
A/6L 614	6(V)	7·98	84/1,800	100/1,800	—	—
A/8L 614	8(V)	10·64	112/1,800	132/1,800	447·6/1,200	1,984
A/12L 614	12(V)	15·96	170/1,800	200/1,800	664·2/1,200	2,770
F/A6L 714	6(V)	9·5	100/1,800	145/2,300	373/1,250	1,775
F/A8L 714	8(V)	12·66	133/1,800	195/2,300	502/1,250	2,095
F/A12L 714	12(V)	19·0	200/1,800	290/2,300	759/1,250	3,020
BF/A12L 714	12(V) S/C	19·0	250/1,800	340/2,250	not available	
MAH 711	1	0·55	5·5/1,500	6/1,500	—	375
MAH 914	1	1·10	11/1,500	12/1,500	—	695
MAH 916	1	1·81	16/1,300	17/1,300	—	960
MAH 320	1	4·02	26/1,000	28/1,000	—	1,720
FIL 712	1	0·85	9/1,800	13/2,300	31·7/1,700	394–414
F2L 712	2	1·7	18/1,800	26/2,300	63·5/1,700	545–576
F3L 712	3	2·55	27/1,800	45/2,800	95·3/1,900	576–606
F4L 712	4	3·4	36/1,800	60/2,800	127/1,900	636–677
F6L 712	6	5·1	54/1,800	90/2,800	190·6/1,900	829–879
F3M 716	3	6·87	82/1,800	100/2,000	275/1,400	1,400
F4M 716	4	9·16	110/1,800	133/2,000	369/1,400	1,695
F6M 716	6	13·74	165/1,800	200/2,000	554/1,400	2,280
BF6M 716	6	13·74	210/1,800	230/1,800	—	2,400
F12M 716	12	27·48	325/1,800	400/2,000	1,110/1,400	4,000
BF12M 716	12	27·48	420/1,800	460/1,800	—	4,200
A4M 517	4	9·02	83/1,500	83/1,500	332/1,000	1,981
A6M 517	6	13·54	128/1,500	128/1,500	512/1,000	2,576
A8M 517	8	18·05	170/1,500	170/1,500	685/1,000	3,192
BA8M 517	8	18·05	250/1,500	250/1,500	953/1,200	3,501
F6M 617	6	13·54	—	175/1,800	362/1,100	2,510
A3M 528	3	31·85	140/750	—	—	7,707
A4M 528	4	42·5	190/750	—	—	9,909
A6M 528	6	63·8	290/750	300/750 (Locomotive)	—	12,111
(Other six- and eight- cylinder models in this series have outputs up to 620 b.h.p.)						
A4M 428	4	42·5	150/600	—	—	8,423
A6M 428	6	63·8	230/600	—	—	11,356
A8M 428	8	85·0	310/600	—	—	14,046

[1] Depending on accessories.
[2] An additional 10 per cent can be added to these figures for a period of 1 hr. in every 6 hr.
[3] This is the automotive rating or maximum allowable for any period.

The majority of the TM series of engines are of "V" formation and are widely used in power stations and for marine propulsion. For the latter type of service the engine can be made directly reversible. They operate on the two-stroke principle, with direct injection and loop scavenging, giving extremely low fuel consumption.

The AM 428 series is a low-speed water-cooled diesel engine (428/600 r.p.m.) of the four-stroke variety using overhead valves operated by a gear-driven camshaft and is supplied in 4-, 6- and 8-cylinder in-line versions. Wet cylinder liners are used and combustion is by direct injection.

The AM 528 series are four-stroke diesels of 3, 4, 6 or 8 cylinders in line with relatively low speeds of 600 to 750 r.p.m. These engines are water cooled and have cylinder liners directly surrounded by the cooling media. The 6- and 8-cylinder engines may be supercharged to 50 to 60 per cent increase in power above that of a naturally aspirated engine; with the 60° boost, a supercharger inter-cooler is required.

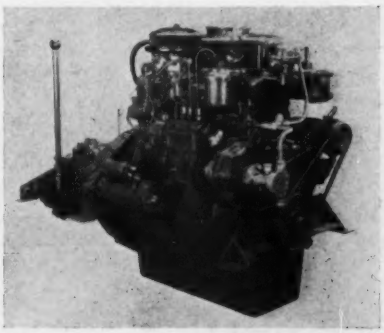
The VM series of engines, used mainly for power stations and marine work, range from 280-3,000 b.h.p.

British Motor Corporation

The water-cooled automotive units are four-stroke engines with overhead valves operated by pushrods from a chain-driven camshaft. The 5·1-litre and 3·4-litre engines

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Automotive						
	6	5·1	63/2,000*	90/2,400	228/1,750	1,045–1,069½
	4	3·4	42·5/2,000*	58/2,400	154/1,500	760
	4	2·2	—	55/3,500	89/2,800	587
Marine Commodore	4	3·4	52/2,400	58/2,400	132/1,500	911 (direct drive)
Commando	4	2·2	46/3,000	55/3,500	84/2,300	725 (direct drive)

*For industrial application these values are for 12-hr. rating.



Marine Commodore.

use wet cylinder liners, with the direct injection type of combustion chamber in the crown of the piston. The smallest engine, the 2·2-litre, has dry cylinder liners and uses the Ricardo Comet III indirect combustion with a compression ratio of 20:1. Heating plugs are used for starting this engine. The marine engines are basically developed from the automotive 3·4- and 2·2-litre engines.

The B.M.C. range of industrial engines are handled by Newage (Manchester) Ltd. (see next month's issue of *Engineering Materials and Design*).

British Polar Engines Ltd.

The smallest engine in the range made by this company is the marine type M.141 which has 4 cylinders and develops 310 b.h.p. at 300 r.p.m., and 400 b.h.p. at 400 r.p.m., the fuel consumption at full load being 0·386 lb./b.h.p./hr. The engine is of the two-cycle single-acting type using direct fuel injection and is reversible; weight is 39,000 lb.

Bristol Siddeley Engines Ltd.

The smallest engines in the range of this company's diesels are the MD.220 and the MD.225, both of which are 4-cylinder in-line four-stroke engines turbo-charged, the MD.225 being fitted with an intercooler. Both engines are part of a range designed specifically for rail traction, marine propulsion and industrial power. The MD.220 and MD.225 each has a capacity of 21·5 litres and for both the turbo-charger is water cooled. In the MD.225 an inter-cooler is fitted to cool the compressed air output from the turbo-charger and increase the specific weight of air entering the cylinders to give an increase in power without an increase in temperature.

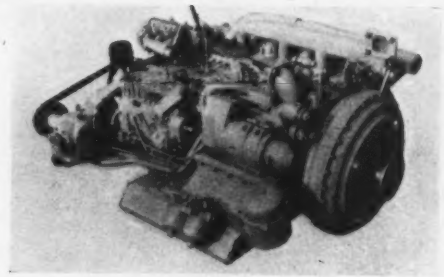
Maximum r.p.m. for both engines is 1,600, at which speed the b.h.p. of the MD.220 is 384 and 445 b.h.p. for MD.225. The maximum torques are 1,300 at 1,200 r.p.m. and 1,520 lb.ft. at 1,300 r.p.m. respectively, the weights being 5,920 and 6,220 lb. The outstanding features of these engines are the pressure-oil-cooled pistons with detachable steel crowns, and roller main bearings for the crankshaft. Two overhead camshafts operate the valves through rockers, three inlet and three outlet valves being used per cylinder. To avoid losses associated with pipes for the fuel from the pump to the cylinder heads, each head incorporafes its own pump operated by the inlet camshaft the injector being positioned in the precombustion chamber.

British United Traction Ltd.

British United Traction Ltd. was formed to co-ordinate the rail traction activities of A.E.C. Ltd. and Leyland Motors Ltd., both of whom have produced high-speed diesel engines for many years. Most of the engines in the B.U.T. range are available in horizontal or vertical form and are 4- and 6-cylinder types.

The 220 and the 680 series are basically similar horizontal four-stroke engines, the difference lying in detail design and the character of the power and torque curves, although for both engines the maximum b.h.p. is obtained at 1,800 r.p.m. Both engines are water cooled and employ dry cylinder liners, the overhead valves being operated by pushrods from a gear-driven camshaft; direct injection of fuel is employed.

The 902 series are horizontal or vertical 6-cylinder direct-injection engines using wet liners and pushrod-operated overhead valves on the gear-driven camshaft. The TS 902 series are similar engines using turbo-charging. The latest addition to the range is type 1100 employing wet cylinder liners externally coated with ceramic to guard against corrosion fatigue. As with other models, the engine is a four-cycle direct-injection type with overhead valves. A turbo-charged version of this engine is known as the TS 1100.



RE 680 Horizontal.

Type	No. of cylinders	Capacity (litres)	Max. power rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Weight including water and oil, etc. (lb.)
220 (Horizontal)	6	11·3	150/1,800	480/1,300	2,082
680 (Horizontal)	6	11·1	150/1,800	475/1,150	2,082
902 (Vertical & Horizontal)	6	15·2	230/1,900	708/1,150	2,838
TS 902 (Vertical & Horizontal)	6	15·7	275/1,800	840/1,200	3,000
1,100 (Vertical & Horizontal)	6	17·9	275/1,900	890/1,300	2,912 dry
TS 1,100 (Vertical & Horizontal)	6	17·9	360/1,900	1,180/1,200	3,000 dry

---

David Brown Construction Equipment Ltd.

The basic designs of this company's diesels are 4- and 6-cylinder overhead valve models operating on the four-stroke principle. Direct injection is used with inlet port designed to promote swirl. Wet replaceable liners are fitted.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Automotive						
	4	2·7	38/2,200	42·5/2,200	112/1,200	600
	6	4·06	45/1,800	50/1,800	152/1,300	890
Marine						
MD4/30	4	2·7	28/1,800	31/1,800	95/1,200	1,230
MD6	6	4·06	45/1,800	50/1,800	152/1,300	1,550

Campbell Oil Engine Co. Ltd.

Type C.1. is a vertical four-stroke single-cylinder engine suitable for industrial application. The other engines tabulated are horizontal four-stroke water-cooled engines also for industrial applications. The cylinder liners are of the wet type and easily renewable, and all engines, except the largest model, can be hand started. With this model, air starting equipment is fitted.

Basic Type	No. of cylinders	Capacity (litres)	Max. continuous power (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
HS6½	1	6·526	15/450	16·5/450	550/450	2,432
HS7½	1	8·689	25/425	27·5/425	900/425	3,836
HS9½	1	18·586	40/350	44/350	1,500/350	6,440
C1	1	1·433	6/650	6·6/650	230/750	890

Caterpillar Tractor Co. Ltd.

A removable precombustion chamber is used in these engines, which have overhead valves and replacable wet liners. Turbo-charged models are also available and may be fitted with after-coolers.

Type	No. of cylinders	Capacity (litres)	Max. continuous power (b.h.p./r.p.m.)	Max. power ⅓ (5 min.) (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Industrial						
D 311 NA	4	4·13	50/2,000	75/2,400	167/1,700	1,225
D 320 T	4	4·13	70/2,000	105/2,400	250/1,700	1,300
D 320 TA	4	4·13	75/2,000	120/2,400	266/1,680	1,340
D 330 T	4	5·74	100/2,000	135/2,200	348/1,650	1,600
D 330 TA	4	5·74	110/2,000	170/2,200	364/1,650	1,630
D 336 NA	6	13·20	137/1,800	200/2,000	604/1,200	3,550
D 333 T	6	8·61	150/2,000	205/2,200	575/1,300	2,100
D 333 TA	6	8·61	165/2,000	255/2,200	645/1,460	2,140
D 342 NA	6	20·43	170/1,200	225/1,300	905/875	5,140
D 337 T	6	13·20	185/1,800	310/2,000	850/1,470	3,700
D 337 TA	6	13·20	200/1,800	345/2,000	990/1,300	3,750
D 342 T	6	20·43	220/1,200	320/1,300	1,120/900	5,340
D 375 NA	V8	27·25	238/1,200	310/1,300	1,118/900	8,215
D 343 TA	6	14·62	280/1,800	430/2,000	965/1,360	4,000
D 353 T	6	24·15	300/1,200	390/1,300	1,500/900	6,230
D 375 T	V8	27·25	325/1,200	430/1,300	1,905/1,000	8,650
D 397 NA	V12	40·88	360/1,200	465/1,300	1,765/900	10,770
D 375 TA	V8	27·25	365/1,200	485/1,300	1,905/1,000	8,960
D 397 T	V12	40·88	500/1,200	650/1,300	2,720/960	11,250
D 397 TA	V12	40·88	550/1,200	730/1,300	2,940/1,125	11,560
Marine						
D 311 NA	4	4·13	50/2,000	75/2,400	167/1,700	1,225
D 320 T	4	4·13	70/2,000	105/2,400	250/1,700	1,400
D 320 TA	4	4·13	80/2,000	130/2,400	266/1,680	1,440
D 330 T	4	5·74	100/2,000	135/2,200	348/1,650	1,630
D 330 TA	4	5·74	120/2,000	180/2,200	364/1,650	1,660
D 336 NA	6	13·20	137/1,800	184/2,000	604/1,200	4,470
D 333 T	6	8·61	150/2,000	205/2,200	575/1,300	2,255
D 342 NA	6	20·43	170/1,225	200/1,300	905/875	5,350
D 333 TA	6	8·61	180/2,000	270/2,200	645/1,460	2,295
D 337 T	6	13·20	185/1,800	310/2,000	850/1,470	3,840
D 342 T	6	20·43	220/1,225	320/1,300	1,120/900	5,500
D 375 NA	V8	27·25	235/1,225	310/1,300	1,118/900	8,325
D 337 TA	6	13·20	240/1,800	365/2,000	990/1,300	3,900
D 353 T	6	24·15	300/1,225	390/1,300	1,500/900	6,610
D 343 TA	6	14·62	310/1,800	460/2,000	965/1,360	4,150
D 375 T	V8	27·25	325/1,225	430/1,300	1,905/1,000	8,950
D 397 NA	V12	40·88	360/1,225	465/1,300	1,765/900	11,100
D 375 TA	V8	27·25	400/1,225	530/1,300	1,905/1,000	9,000
D 397 T	V12	40·88	500/1,225	650/1,300	2,720/960	11,650
D 397 TA	V12	40·88	600/1,225	780/1,300	2,940/1,125	11,700

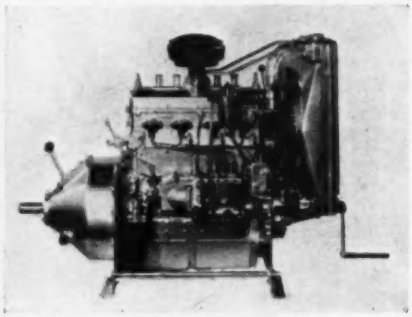
NA = Naturally aspirated.
T = Turbo-charged.
TA = Turbo-charged and after-cooled.

Coventry Diesel Engines Ltd.

The model CD 2 is primarily for duty in industrial and mobile applications and is a twin-cylinder, four-stroke push-rod-operated O.H.V. engine with a chain-driven camshaft. A special feature is the balancing gear permitting equally spaced firing impulses.

Model CD 4 is also for industrial application and is a 4-cylinder engine of similar design to the CD 2. Both these engines have precombustion chambers, and all engines have dry cylinder liners.

The CD 4 and KF 4 are engines both with 4 cylinders, the CD 4 (marine) being basically identical to the industrial version. The KF 4 (Marine) is a 4-cylinder, two-stroke, uniflow blower scavenged, with direct fuel injection and designed under Kadenacy Patents. Special features include compact dimensions, light weight and an epicyclic oil-operated reverse gear and electric starting.



CD 4 Industrial.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Net weight (lb.)
CD 2	2	1·12	15/2,000	16·5/2,000	41/1,800	630 (including electric starting)
CD 4 (industrial)	4	2·68	36/2,000	39·6/2,000	95/1,800	580 (bare)
CD 4 (marine)	4	2·25	30/2,000	33/2,000	82/1,800	885 (including electric starting and reverse gear)
KF 4	4	1·76	50/2,000	55/2,000	130/1,500	690 (including epicyclic oil-operated reverse gear and electric starting)

Cummins Engines Co. Ltd.

The Cummins range of diesel engines manufactured in Great Britain includes nineteen basic types with powers from 110 to 380 b.h.p. All models are four-stroke engines and except for models H, HR and HRF, which have one inlet and one exhaust valve, all are designed with two exhaust and two inlet valves per cylinder. Open-type combustion chambers are employed with direct injection, the overhead valves being operated by pushrods from a geared camshaft. Wet cylinder liners are used, and these are coated with a special material to give a rapid running-in and subsequent long life. Certain of the engines use a turbo-charger for developing additional power, while the supercharged engines employ a Rootes-type blower.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Net weight (lb.)
NHC-4*	4	8·1	91/1,800	125/2,100	370/1,300	1,815
H-6*	6	11·0	120/1,800	154/1,800	492/1,200	2,270
HU-6*	6	11·0	124/1,800	158/1,800	520/1,050	2,270
NT-4* (turbo-charged)	4	8·1	117/1,800	168/2,100	470/1,500	1,875
HR-6*	6	12·2	132/1,800	168/1,800	530/1,250	2,270
NH-180*	6	11·0	123/1,800	173/2,100	495/1,300	2,340
HRF-6*	6	12·2	136/1,800	184/2,000	555/1,300	2,325
NH-195*	6	11·0	132/1,800	188/2,100	515/1,300	2,340
NH-220*	6	12·2	150/1,800	212/2,100	585/1,300	2,360
NT-6* (turbo-charged)	6	12·2	170/1,800	250/2,100	710/1,300	2,455
NTO-6* (turbo-charged)	6	12·2	178/1,800	262/2,100	740/1,300	2,455
NHS-6* (supercharged)	6	12·2	200/1,800	278/2,100	790/1,350	2,660
NRT-6* (turbo-charged)	6	12·2	205/1,800	305/2,100	870/1,300	2,465
NHRS-6* (supercharged)	6	12·2	216/1,800	305/2,100	830/1,600	2,660
NRTO-6* (turbo-charged)	6	12·2	223/1,800	335/2,100	920/1,300	2,465
J-70	4	4·38	48/1,800	67·5/2,000	191/1,300	1,150
J-80	4	4·38	48/1,800	77/2,500	191/1,400	1,180
C-90	4	5·06	62/1,800	87/2,000	238/1,475	1,155
J-6	6	6·57	75/1,800	96/1,800	293/1,450	1,445
C-105	4	5·06	72/2,200	101/2,500	238/1,500	1,155
JF-6	6	6·57	79/2,000	106/2,200	292/1,450	1,485
HRC-4*	4	8·1	86/1,800	110/1,800	360/1,200	1,755
JN-130	6	6·57	92/2,200	125/2,500	320/1,500	1,500
C-160	6	7·6	112/2,200	154/2,500	362/1,400	1,500
JS-6	6	6·57	111/2,200	154/2,500	360/1,700	1,540
JNS-6	6	6·57	123/2,200	169/2,500	391/1,750	1,550
C-180	6	7·6	128/2,200	173/2,500	410/1,700	1,550
JT-6	6	6·57	122/2,200	175/2,500	407/1,750	1,553
C-175	6	7·6	124/2,200	175/2,500	405/1,750	1,555
C-200	6	7·6	137/2,200	200/2,500	465/1,750	1,555
HS-6	6	11·0	157/1,800	202/1,800	647/1,250	2,475
HRS-6	6	12·2	180/1,800	231/1,800	725/1,300	2,485
NH-250*	6	14·0	172/1,800	240/2,100	660/1,400	2,530
NT-280*	6	12·2	188/1,800	280/2,100	770/1,500	2,465
NT-380*	6	14·0	244/1,800	380/2,300	1,000/1,400	2,750
NVH-12	12	24·55	308/1,800	432/2,100	1,235/1,500	5,150
VT-12	12	24·55	412/1,800	600/2,100	1,635/1,500	5,610

*These engines are manufactured in Great Britain.

Daimler (Transport Vehicles (Daimler) Ltd.)

The CD 650 and D 650H are basically similar engines in design, the D 650H differing only by the cylinders being in a horizontal plane. Both employ dry cylinder liners and overhead valves operated by pushrods from a gear-driven camshaft. Direct fuel injection is employed. The normally aspirated CD 6 Mk. VIII and the turbo-charged version are of similar design to the CD 650.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.) (Automotive)	Max. power (b.h.p./r.p.m.) (12 hr. rating)	Max. torque (lb. ft./r.p.m.)	Net dry weight (lb.)
CD 650	6	10·62	150/2,000	123/2,000	460/1,000	2,029
D 650H	6	10·62	150/2,000	123/2,000	460/1,000	1,884
CD 6 Mk. VIII	6	8·6	125/2,000	102/2,000	360/1,200	1,585
CD 6 Mk. VIII (turbo-charged)	6	8·6	150/2,000	123/2,000	460/1,200	—

This comprehensive survey of diesel engines will be continued in the December issue.

RUSSIAN TECHNICAL TRANSLATIONS

by H. L. R. HINKLEY

The recent technological advances have been accompanied by a corresponding increase in the number of technical journals, and a designer could well spend all his time keeping abreast of current developments. The knowledge that Russian technology in many spheres appears to be in advance of that of the Western world has increased the amount of technical literature by the addition of various Russian translations. It will be initially helpful to the designer to know which Russian journals have been translated into English. The following tables indicate the equivalent English titles, the source, the number of issues per annum and the price.

RUSSIAN JOURNALS AVAILABLE IN ENGLISH

(A)—American tr.—full translation.
(B)—British abs.—abstracts only.

Classification	*Title*	*English Translation Available from:*	*Issues per Annum*	*Cost*
Agriculture and Botany	Doklady Akademiya Nauk. SSSR. Otdel Agrokhimii. (Proceedings of the Academy of Sciences of the U.S.S.R.—agrochemistry section.)	C.B.I.(N.S.F.) (A) tr.	6	$15
	Pochvovedeniye. (Soil Science.)	A.I.B.S. (A) tr.	12	$40
	Doklady Akademiya Nauk. SSSR. (Proceedings of the Academy of Sciences of the U.S.S.R.—botanical science papers.)	A.I.B.S.(N.S.F.)	6	$7.50
	Fiziologiya Rastenii. (Plant Physiology.)	A.I.B.S.	6	$15
Astronomy	Astronomicheskiy Zhurnal. (Astronomical Journal—Soviet Astronomy—AJ.)	A.I.P.(N.S.F.) (A) tr. O.T.S. (A) abs.	6 6	$27 $13
	Referativny Zhurnal. (Abstracts Journal: astronomy and geodesy.)	O.T.S. (A) abs.	12	$6
	Vestnik Leningrad University Herald. (Mathematics, mechanics, astronomy series.)	O.T.S. (A) abs.	4	$2
Biology and Medicine	Biofizika. (Biophysics.)	P.P. (A) (B) tr.	8	£10.14s ($30)
	Biokhimiya. (Biochemistry.)	C.B.I. (A) tr.	6	$20
	Byulleten' Eksperimental'noi Biologii i Meditsiny. (Bulletin of Experimental Biology and Medicine.)	C.B.I. (A) tr.	12	$20
	Doklady Akademiya Nauk. SSSR. Otdel Biokhimii. (Proceedings of the Academy of Sciences of the U.S.S.R.—biochemistry section.)	A.I.B.S. tr.	—	$15
	Doklady Akademiya Nauk. SSSR. (Proceedings of the Academy of Sciences of the U.S.S.R.—biological science papers.)	A.I.B.S. tr.	6	$20

Classification	Title	English Translation Available from:	Issues per Annum	Cost
Biology and Medicine (cont.)	Referativny Zhurnal: Biologiya. (Abstracts Journal: biology section.)	O.T.S. (A) abs.	12	$12
	Uspekhi Sovremennoi Biologii. (Russian Review of Biology.)	O. & B. (B) tr.	6	£6.10s
	Mikrobiologiia. (Microbiology.)	A.I.B.S.(N.S.F.)	6	$20
	Entomologicheskoye Obozreniye. (Entomological Review.)	A.I.B.S. tr.	—	$25
	Antibiotiki. (Antibiotics.)	C.B.I. (A) tr.	6	$25
	Farmakologiia i Toksikologiia. (Pharmacology and Toxicology.)	C.B.I. (A) tr.	6	$25
	Fiziologicheskiy Zhurnal SSSR. im. I.M. Sechenova. (I.M. Sechenova Physiological Journal.)	P.P. (A) (B) tr.	12	£16 ($45)
	Problemy Gematologii i Perelivaniya. (Problems of Hematology and Blood Transfusion.)	P.P. (A) (B) tr.	6	£7 ($20)
	Abstracts of Soviet Medicine.			
	Part A: Basic Medical Sciences.	E.M.F. (A) tr.	4	$15 with Part B $25
	Part B: Clinical Medicine.	E.M.F. (A) tr.	4	$15 with Part A $25
	Voprosy Virusologii. (Problems of Virology.)	P.P. (A) (B) tr.	6	£7 ($20)
	Voprosy Onkologii. (Problems of Oncology.)	P.P. (A) (B) tr.	6	£10.14s ($30)
	Zhurnal Mikrobiologii Epidemiologii i Immunologii. (Journal of Microbiology, Epidemiology and Immunobiology.)	P.P. (A) (B) tr.	12	£17.14s ($50)
		O.T.S. (A) abs.	—	$6
	Zhurnal Vysshey Vervnoy Deyatel'nosti im Pavlova. (Pavlov Journal of Higher Nervous Activity.)	P.P. (A) (B) tr.	—	£10.14s ($30)
Chemistry	Doklady Akademiya Nauk. SSSR. Otdel Khimicheskaya Tekhnologiya. (Proceedings of the Academy of Sciences of the U.S.S.R.—chemical technology section.)	C.B.I. (A) tr.	6	$15
	Doklady Akademiya Nauk. SSSR. Otdel Khimii. (Proceedings of the Academy of Sciences U.S.S.R.—Chemistry section.)	C.B.I. (A) tr.	6	$95
	Doklady Akademiya Nauk. SSSR. Otdel Fizicheskoy Khimii. (Proceedings of the Academy of Sciences of the U.S.S.R.—physical chemistry section.)	C.B.I. (A) tr.	6	$160
	News of the Academy of Sciences U.S.S.R. Department of Chemical Sciences.	O.T.S. (A) abs.	12	$6
	Izvestiya Akademii Nauk. SSSR. Otdeleniye Khimicheskikh Nauk. (Bulletin of the Academy of Sciences of the U.S.S.R. —Division of chemical science.)	C.B.I. (A) tr.	12	$45
	Khimicheskaya Nauki i Promyslennost. (Chemical Science and Industry.)	O.T.S. (A) abs.	6	$3
	Khimicheskaya Promyslennost. (Chemical Industry.)	O.T.S. (A) abs.	8	$4
	Kolloidnyi Zhurnal. (Colloid Journal.)	C.B.I. (A) tr.	6	$80
		O.T.S. (A) abs.	6	$3
	Krystallografiya. (Soviet Physics—crystallography.)	A.I.P.(N.S.F.) (A) tr.	6	$27
		O.T.S. (A) abs.	6	$3
	Referativny Zhurnal. Chemistry Section.	O.T.S. (A) abs.	24	$12
	Zhurnal Neorganicheskoi Khimii. (Journal of Inorganic Chemistry.)	C.S. C.-H.P. (B) tr.	12	£30
		O.T.S. (A) abs.	—	$6
	Ukrainski Khimicheskii Zhurnal.	O.T.S. (A) abs.	6	$3
	Uspekhi Khimii. (Chemical Review.)	C.S. C.-H.P. (B) tr.	—	£12 ($36)
		O.T.S. (A) abs.	12	$6
	Zhurnal Analiticheskoi Khimii. (Journal of Analytical Chemistry.)	C.B.I. (A) tr.	6	$80
		O.T.S. (A) abs.	—	$3
	Zhurnal Fizicheskoi Khimii. (Journal of Physical Chemistry.)	C.S. C.-H.P. (B) tr.	12	£30
	Zhurnal Obschchey Khimii. (Journal of General Chemistry.)	C.B.I. (A) tr.	12	$90
		O.T.S. (A) abs.	12	$6
	Zhurnal Prikladnoy Khimii. (Journal of Applied Chemistry.)	C.B.I. (A) tr.	12	$60
		O.T.S. (A) abs.	—	$6
	Khimiya i Teknologiya Toplivi Masel. (Chemistry and Technology of Fuels.)	O.T.S. (A) abs.	12	$16
	Koks i Khimiya. (Coke and Chemistry.)	D.S.I.R. (B) tr.	12	£5.5s
		O.T.S. (A) abs.	12	$6
	Zarodskaya Laboratoriya. (Factory Laboratory.)	I.S.A. tr.	—	$35
Economics and Education	Voprosy Ekonomiki. (Problems of Economics.)	I.A.S.P. (A) tr.	—	$50
	Sovetskaya Pedagogika. (Soviet Education)	I.A.S.P. (A) tr.	—	$70
Engineering	Atomnaya Energiya. (Atomic Energy.) Certain papers included in the International Journal of Nuclear Energy.	P.P. (A) tr.	3	$20 per vol.
	Atomnaya Energiya. (Atomic Energy.)	C.B.I.(N.S.F.) (A) tr.	12	$75
		O.T.S. (A) abs.	12	$6
(Aeronautical)	Vestnik Vozdushnogo Flota. (Herald of the Air Fleet.)	O.T.S. (A) abs.	12	$6
	Grazhdanskiya Aviatsiya. (Civil Aviation.)	O.T.S. (A) abs.	12	$6
	Trudy Moskovskoyo Aviatsionoga Institute. (Transactions.)	O.T.S. (A) abs.	—	50c.
(Automation)	Avtomatika i Telemekhanika. (Automation and Remote Control.)	I.S.A. (A) tr.	12	$30
	Automation Express.	I.P.I. (A) tr.	10	$57.50
(Electrical)	Elektrichestvo. (Soviet Journal of Electrical Technology.)	P.P. (A) (B) tr.	4	£6 ($17) per vol. or £20 ($56) p.a.
	Elektrosvyaz. (Telecommunications.)	P.P. (M.I.T./N.S.F.) (A) (B) tr.	12	£10.14s ($30)
		O.T.S. (A) abs.	12	$6
	Referativny Zhurnal. (Abstracts Journal: electrical engineering.)	O.T.S. (A) abs.	12	$6
	Electronics Express	I.P.I. (A) tr.	10	$57.50
(Instrument)	Izmeritel'naya Tekhnika. (Measurement Technique.)	I.S.A. (N.S.F.) (A) tr.	8	$25
	Pribory i Tekhnika Eksperimenta. (Instruments and Experimental Technique.)	I.S.A. (N.S.F.) (A) tr.	6	$25
	Priborostronie. (Instrument Construction.)	B.S.I.R.A. (D.S.I.R.)][T&F (B) tr.	12	

Classification	Title	English Translation Available from:	Issues per Annum	Cost
(Materials)	Tsement. (Cement.)	C.B.I. (A) tr.	—	$60
	Kauchuk i Rezina. (Soviet Rubber Technology.)	R.A.B.R.M. (D.S.I.R.) M&S (B) tr.	12	£10.10s ($50)
		O.T.S. (A) abs.	12	$6
	Steklo i Keramika. (Glass and Ceramics.)	C.B.I. (A) tr.	12	$80
		O.T.S. (A) abs.	—	$6
(Mechanical)	Avtomaticheskaya Svarka. (Automatic Welding.)	B.W.R.A. (D.S.I.R.) (B) tr.	12	£10.10s
	Kholodilnaya Tekhnika. (Refrigeration Engineering.)	O.T.S. (A) abs.	4	$2
	Referativny Zhurnal. (Abstracts Journal: machine design.)	O.T.S. (A) abs.	24	$12
	Stanki i Instrumenti. (Machines and Tools.)	P.E.R.A. (D.S.I.R.) (B) tr.	12	£3.10s
	Svarochnoc Proisvodstro. (Welding Production.)	B.W.R.A. (D.S.I.R.) (B) tr.	12	£5.10s
	Vestnik Maschinoshoeniya.	P.E.R.A. (D.S.I.R.) (B) tr.	12	£8
	Derevoobrabatyvayushishaya Promyslennost. (Wood Working Industry.)	D.S.I.R. (B) tr.	—	£5.5s.
(Metallurgy)	Fiziki Metallov i Metallovedeniye. (Physics of Metals and Metallography.)	P.P.(N.S.F.) (A)(B) tr.	6	£10.14s ($30)
	Metallovedeniye i Obrakotba Metallov. (Metals and Treatment of Metals.)	H.B. (A)	—	—
	Tsvetnye Metally. (Non-ferrous Metals.)	P.S. (A) tr.	12	$97
(Patents and Inventions)	Buylleten Izobretenii. (Patents and Inventions.)	P.P. (A) (B) tr.	24	£25–£30 (single copies 7s)
(Radio)	Radiotekhnika. (Radio Engineering.)	P.P. (M.I.T./N.S.F.) (A) (B) tr.	12	£10.14s ($30)
		O.T.S. (A) abs.	12	$6
	Radiotekhnika i Elektronika. (Radio Engineering and Electronics.)	P.P. (M.I.T./N.S.F.) (A) (B) tr.	12	£16 ($45)
		O.T.S. (A) abs.	12	$6
	Zarodskaya Laboratinia. (Industrial Laboratory.)	I.S.A. (A) tr.	12	$35
Geodesy, Geography and Geology	Doklady Akademii Nauk. SSSR. Otdel Geokhimii. (Proceedings of the Academy of Sciences of the U.S.S.R.—geochemistry section.)	C.B.I. (A) tr.	6	$15
	Doklady Akademii Nauk. SSSR. Otdel Geologii. (Proceedings of the Academy of Sciences of the U.S.S.R.—geology section.)	C.B.I. (A) tr.	6	$200
	Geokhimiya. (Geochemistry.)	G.S. (A) tr.	8	$18
	Geologiya Nefti (Petroleum Geology.)	R.R.G. (A)	—	—
	Izvestiya Akademii Nauk. SSSR. Seriya Geologicheskaya. (Bulletin of the Academy of Sciences of the U.S.S.R. geology series.)	A.G.I. (A)	—	$45
	Izvestiya Akademii Nauk. SSSR. Seriya Geofizicheskaya. (Bulletin of the Academy of Sciences of the U.S.S.R.—geophysical series.)	P.P. (A) (B) tr.	12	£9.10s ($25)
	Referativny Zhurnal. (Abstracts Journal: astronomy and geodesy.)	O.T.S. (A) abs.	12	$6
	English Language Abstracts Journal in the Field of Geophysics.	P.P. (B) tr.	6	£18
	Referativny Zhurnal. (Abstracts Journal: geography.)	O.T.S. (A) abs.	12	$6
	Referativny Zhurnal: Geologiya. (Abstracts Journal: geology.)	A.G.I.(N.S.F.) (A)tr.	—	$40
		O.T.S. (A) abs.	12	$6
Mathematics	News of the Academy of Sciences. (Mathematics Series.)	O.T.S. (A) abs.	6	$3
	Matematicheskii Sbornik. (Mathematics Symposium.)	O.T.S. (A) abs.	12	$6
	Prikladnaiya Matematika i Mekhanika. (Journal of Applied Mathematics and Mechanics.)	P.P. (A.S.M.E./N.S.F.) (A) (B) tr.	6	£12.19s ($35)
		O.T.S. (A) abs.	6	$3
	Referativny Zhurnal. (Abstracts Journal: mathematics.)	O.T.S. (A) abs.	12	$6
	Referativny Zhurnal. (Abstracts Journal: mechanics.)	M.A. (B) abs.	12	Free
	Teoriya Veroyatnostey i Primeniya. (Theory of Probability and its Applications.)	S.I.A.M.(N.S.F.) tr.	3	$18
	Ukrainskii Matematicheskii Zhurnal.	O.T.S. (A) abs.	4	$2
	Uspekhi Matematicheskii Nauk. (Progress Mathematical Science.)	O.T.S. (A) abs.	6	$3
	Vestnik Leningrad Universit. (Herald). (Mathematics, Mechanics, Astronomy Series.)	O.T.S. (A) abs.	4	$2
(Cybernetics)	Problems of Cybernetics.	P.P. (B) tr.	—	£10
Physics	Akusticheskiy Zhurnal. (Soviet Physics—Acoustics.)	A.I.P.(N.S.F.) (A) tr.	4	$14
		O.T.S. (A) abs.	4	$2
	Czechoslovak Journal of Physics.	C.B.I. (A) tr.	6	$50
	Dokaldy Akademii Nauk. SSSR. (Soviet Physics—Doklady.)	A.I.P.(N.S.F.) (A) tr.	6	$35
	Doklady Akademii Nauk. SSSR. Otdel Prikladnoy Fiziki. (Proceedings of the Academy of Sciences—applied physics section.)	C.B.I. (A) tr.	6	$200
	Fiziki Tverdogo Tela. (Soviet Physics—solid state.)	A.I.P.(N.S.F.) (A) tr.	12	$55
	Doklady Akademiya Nauk. SSSR. Physics Papers. (Proceedings of the Academy of Sciences—physics papers.)	A.I.P. (N.S.F.) (A) tr.	—	$35
	Izvestiya Akademii Nauk. SSSR. Seriya Fizicheskaya. (Bulletin of the Academy of Sciences of the U.S.S.R.—physics series.)	C.T.T. (A) tr.	—	$215
	Optika i Spectroskopiya. (Optics and Spectroscopy.)	O.S.A.(N.S.F.) (A) tr.	12	$28
	Referativny Zhurnal. (Abstracts Journal: physics.)	O.T.S. (A) abs.	12	$6
	Uspekhi Fizicheskikh Nauk. (Advances in the Physical Sciences.) (Soviet Physics—Uspekhi.)	A.I.P.(N.S.F.) (A) abs.	6	$14
	Zhurnal Eksperimental'noy i Teoreticheskoy Fiziki. (Journal of Experimental and Theoretical Physics.) (Soviet Physics—J.E.T.P.)	A.I.P.(N.S.F.) (A) tr.	12	$79
		O.T.S. (A) abs.	—	$6
	Zhurnal Tekhnicheskoy Fiziki. (Journal of Technical Physics.) (Soviet Physics—technical physics.)	A.I.P.(N.S.F.) (A) tr.	12	$59
	Physics Express	I.P.I. (A) tr.	—	$57.50
Photography	Zhurnal Nauk. Priklad Fot. Kinemat. (Journal of Scientific and Applied Photography and Cinematography.)	O.T.S. (A) abs.	6	$3

KEY TO ABBREVIATIONS

A.G.I.
American Geological Institute,
2101 Constitution Avenue, N.W.,
Washington, 25, D.C.,
U.S.A.

A.G.U.
American Geophysical Union,
1515 Massachusetts Avenue, N.W.,
Washington, 5, D.C.,
U.S.A.

A.I.B.S.
American Institute of Biological Sciences,
2000 Pea Street, N.W.,
Washington, 6, D.C.,
U.S.A.

A.I.P.
American Institute of Physics,
335 East 45th Street,
New York, 17, N.Y.,
U.S.A.

B.W.R.A.
British Welding Research Association,
29 Park Crescent,
London, W.1.

C.B.I.
Consultants Bureau Inc.,
227 West 17th Street,
New York, 11, N.Y.,
U.S.A.

C.-H.P.
Cleaver-Hume Press Ltd.,
31 Wright's Lane,
London, W.8.

C.S.
Chemical Society, London.

C.T.T.
Columbia Technical Translations,
5 Vermont Avenue,
White Plains,
New York,
U.S.A.

D.S.I.R.
Department of Scientific and Industrial Research,
Charles House,
Lower Regent Street,
London, S.W.1.

E.M.F.
Excerpta Medica Foundation,
2 East 103rd Street,
New York, 29, N.Y.
U.S.A.

G.S.
Geochemical Society,
c/o Dr. Earl Ingerson,
University of Texas,
Austin, 12,
Texas,
U.S.A.

H.B.
Henry Brutcher,
Technical Translations,
P.O. Box 157,
Altdena,
California,
U.S.A.

I.A.S.P.
International Arts and Sciences Press,
33 West 42nd Street,
New York, 36, N.Y.,
U.S.A.

I.P.I.
nternational Physical Index,
1909 Park Avenue,
New York, 35, N.Y.,
U.S.A.

I.S.A.
Instrument Society of America,
313 Sixth Avenue,
Pittsburgh, 22, Pa.,
U.S.A.

I.S.I.
Iron and Steel Institute,
4 Grosvenor Gardens,
London, S.W.1.

M. & S.
MacLaren & Sons Ltd.,
131 Great Suffolk Street,
London, E.C.1.

M.I.T.
Massachusetts Institute of Technology.

N.S.F.
National Science Foundation.

O. & B.
Oliver & Boyd Ltd.
39A Welbeck Street,
London, W.1.

O.S.A.
Optical Society of America,
2500 South State Street,
Ann Arbor,
Michigan,
U.S.A.

O.T.S.
Office of Technical Services,
U.S. Department of Commerce,
Washington, D.C.,
U.S.A.

P.E.R.A.
Production Engineering Research Association,
Melton Mowbray,
Leics.
England

P.P.
Pergamon Press Inc.,
125 East 55th Street,
New York, 22, N.Y.
U.S.A.

Pergamon Press Ltd.,
4/5 Fitzroy Square,
London, W.1.

P.S.
Primary Sources,
Department T-C,
11 Bleecker Street,
New York, 12, N.Y.
U.S.A.

R.A.B.R.M.
Research Association of British Rubber Manufacturers,
Shawbury,
Shrewsbury, Salop,
England.

R.R.G.
Review of Russian Geology,
555 Harden Street,
Columbia,
South Carolina,
U.S.A.

S.I.A.M.
Society for Industrial and Applied Mathematics,
Box 7541,
Philadelphia, 1,
Pennsylvania,
U.S.A.

T. & F.
Taylor & Francis Ltd.,
Red Lion Court,
Fleet Street,
London, E.C.4.

NEW IDEAS IN DESIGN

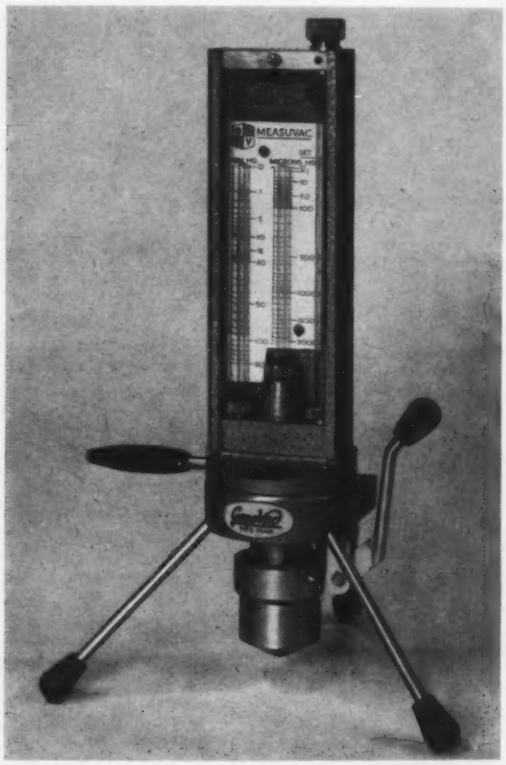
Outstanding products in current manufacture

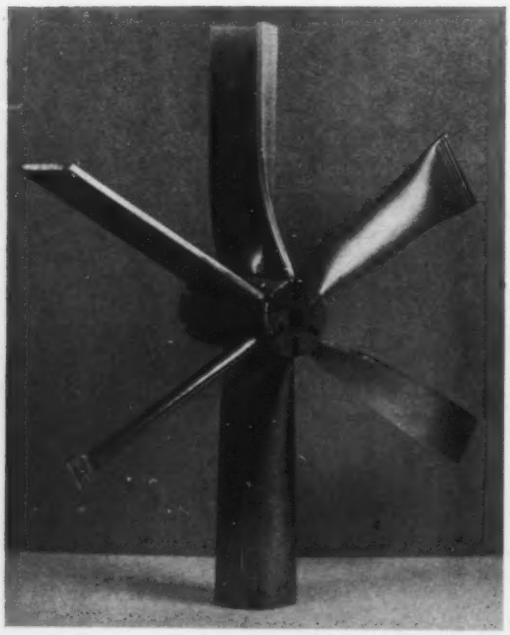
Miniature McLeod Gauge

FOR the first time, Genevac Ltd., of Radcliffe, Lancs., have produced a McLeod gauge of very small proportions covering a range of pressure hitherto not possible. This instrument is a general-purpose vacuum gauge which is said to give accurate and rapid pressure readings even under the most exacting conditions. The standard model (see illustration) covers the range 150 mm. to 1 micron. This is achieved by the simple operation of depressing a lever which gives accurate readings simultaneously on two scales, one reading from 2-150 mm., and the other 1-2,000 microns.

To take a reading, one depresses the handle and the mercury rises in the three tubes. The rising level in the left-hand intake tube is then adjusted to the set mark position. With this held steady a pressure reading is taken on the scale, appropriate to the pressure range. Once the reading has been taken the operating lever is released and the mercury returns automatically to zero ready for the next reading. This eliminates any possibility of mercury being left in the tubes, and resultant damage if the pressure should rise to atmosphere.

The reading capillary tubes are completely separate and easily detachable from the main body by means of the knurled sealing gland. Also, due to the reproducible accuracy between each gauge, replacement scales, glasses or bodies may be made without any calibration, and the volume of mercury required for these gauges is not critical. The glass-work is easily removed by means of the demountable O ring joints, cleaned in the normal way and replaced again in a very short time. Where necessary, the whole mercury tank can be dismantled by means of the four clamping screws, and the complete mechanism exposed for this operation.

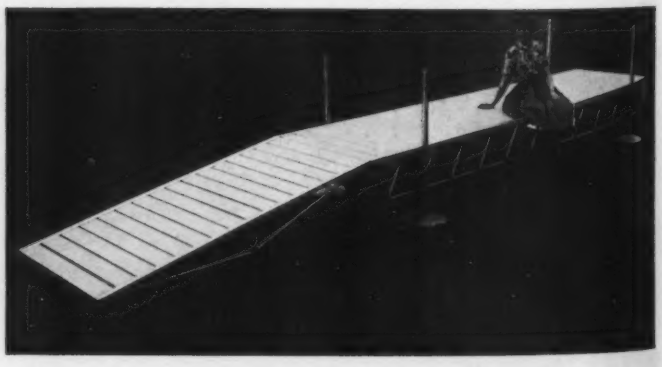




Extruded Connecting Hubs for Frameworks

THE Triodetic system, recently introduced by F. Fentiman & Sons Ltd., of Ottawa, Ontario, enables a great variety of light-alloy structures to be produced without the use of rivets, bolts or welding.

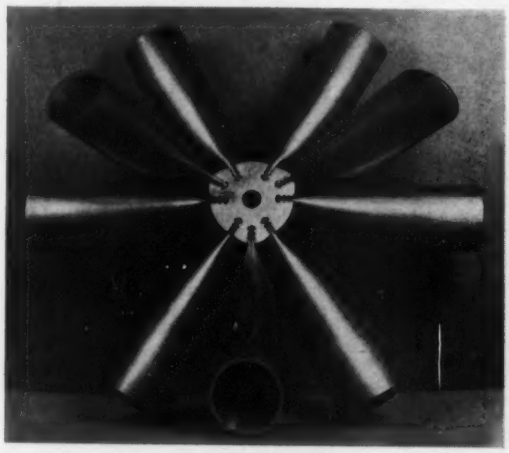
The system relies on a patented system of extruded connecting hubs, such as those illustrated. The serrated slots are used to receive the connecting members which, although generally of tubular section, can also be of plate or rod. The structural members are prepared for connection



by a pressing operation which closes the ends and forms the metal to fit the hub slots. The forming is done when the metal is in the soft annealed state, the tubes being later heat treated to restore full structural strength. In forming the tubes no metal is removed, it is only displaced. This gives the effect of a tapered thread with gradual transfer of load. Assembly is carried out by merely slipping the formed tube into the hub. The resulting connections are claimed to have a structural efficiency greater than 90 per cent in tension, and it is stated that, in test, failure often occurs away from the connections in the plain tube.

A feature making for simplicity is that only one hub section is required for a given tube wall thickness. For larger or smaller tubes of the same wall thickness it is only necessary to cut the hub section in appropriate lengths. An important advantage claimed for the system is the great intrinsic accuracy attainable. The hubs, being extruded, are naturally accurate and it is claimed that tube lengths can be controlled by means of jigs to within $\pm 0{\cdot}003$ in. Depending on application, hubs may be produced with various numbers and positions of slots. Special configurations are easily managed.

With the Triodetic system, not only are planar frames (such as trusses) easily fabricated, but true space frames can also be produced. Applications include conventional and unconventional structures, buildings, radio telescopes and radar screens, special structures for prefabrication and air transport, wharf and pier structures, display frames and ramps (see illustration). Although Triodetic is not, strictly speaking, a prefabricated system, it has the undoubted advantage of such systems that the structures made with it can be assembled on site by unskilled labour.

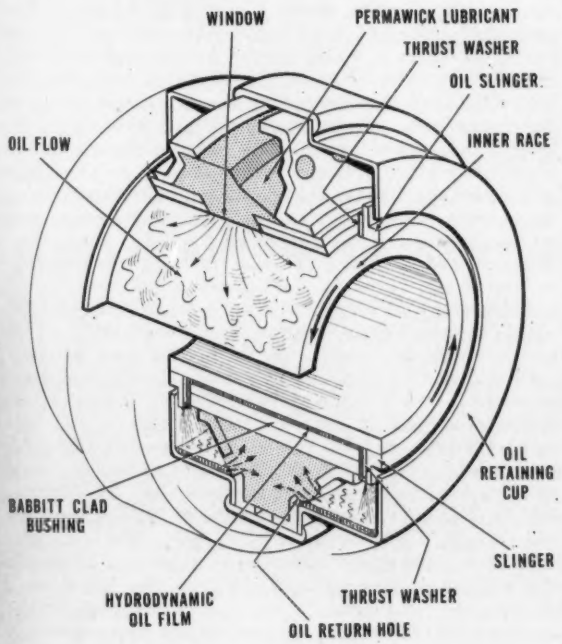


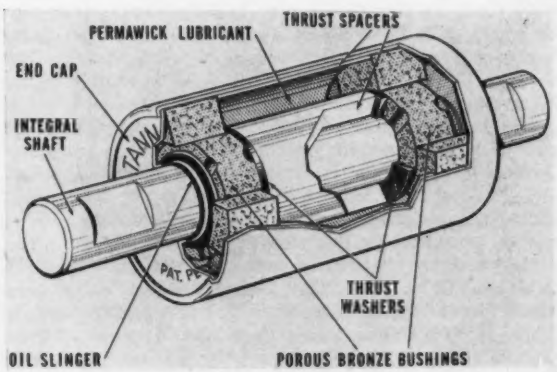
New Bearing Avoids Metal-to-metal Contact

A NEW range of bearings known as Hy-Film, introduced by the Tann Bearing Co. division of Tann Corp., Detroit, operates on a hydrodynamic film principle. As metal-to-metal contact is avoided, the bearings are claimed to be practically wear free and able to provide 20,000 hr. base life without the need for periodic lubrication.

The manner in which the lubrication of the bearings is achieved is shown in the sectional illustration. A wick lubricator of a patented material known as Permawick surrounds the inner race. Oil from this reservoir is supplied to the outside surface of the inner race, and is drawn there in the form of a film by rotation. In this way the inner race is supported on a hydrodynamic film. Pressure on the film causes the oil to be forced to the bearing ends, where it serves to lubricate a thrust washer sealing arrangement On leaving the washer, the oil is picked up by a slinger and returned to the oil-retaining cup, from which it is reabsorbed by the Permawick material.

In addition to the Hy-Film range of bearings, the Tann Bearing Co. also produce a new shaft-bearing assembly which is claimed to have a life expectancy several times that of conventional roller, ball or needle bearing devices, to run quieter, and to never need re-oiling. It is recommended for applications where bearing noise or conducted resonances are a problem.





RUSSIA REVISITED

Thirty years ago the author was in Soviet Russia for a time. Recently he went there again to find out what progress had been made since then. Some of his comments are given in the following article

by ERIC N. SIMONS

ONE of the most striking items was an apparatus for welding by ultrasonic methods. By this means sheets of metal may be successfully united in a way which would not be possible with the standard welding processes. In addition, it is possible with this unit to weld foil less than one tenth of a mm. in thickness. The Soviets have also developed plastic dies for the production of steel machine parts. These are said to be extremely effective, and to reduce the amount of labour required in stamping by as much as two thirds. The U.S.S.R. does not claim to be the only country using these methods, but the significant fact is that they have reached the stage at which innovations of this kind can be introduced and operated without danger of failure.

Another novelty was a radio-tape recorder, with seven valves, push-button control and four loud speakers for stereo sound. The tape-recorder is on top of the radio, where normally a record-player might be built in. Recording may be conducted either with the aid of a microphone or directly from the radio receiver. Production of this began in August 1959.

One advance which I had the opportunity of inspecting was the first screw-cutting lathe made largely of plastics; this was made in Moscow. Its speed and durability during trials are said to prove that it is superior to similar all-metal machines. The Soviets claim that they are now beginning to produce automobiles, calculating machines, instruments and even ships in which plastics are widely used.

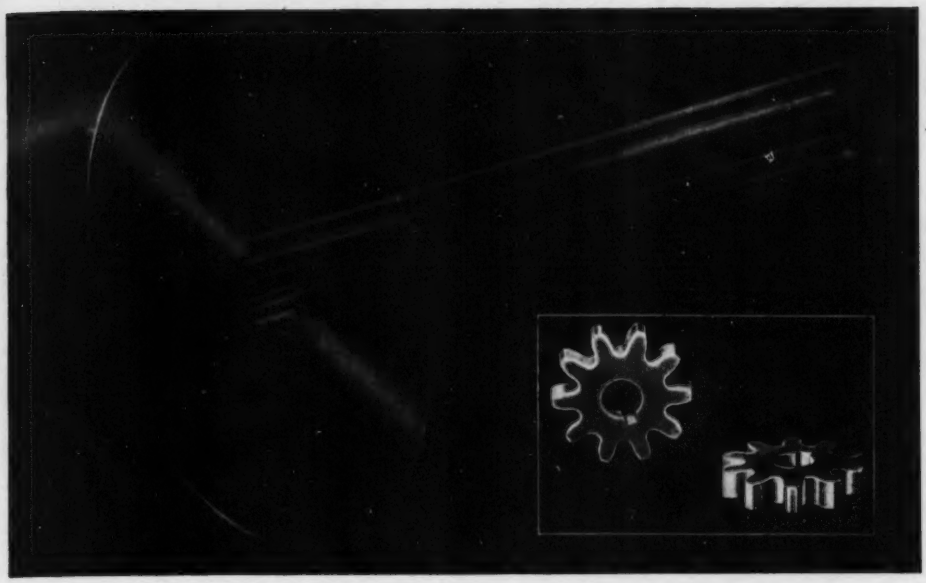
One of the most sensational novels to come out of the U.S.S.R. was Dudintsev's "Not by Bread Alone", which mentioned the inventor of a machine for casting pipe continuously. It is interesting therefore that the Soviets have just completed designs for an automated production line for the centrifugal casting of iron pipes for water mains. This line includes six centrifugal machines which will cast pipes 150 mm. in dia. and 6·5 metres long. Cast at the rate of 120/hr., the pipes will be conveyed to a furnace to be annealed and then treated by another machine that will strip the scale on the inside wall. Finally, they will be put through a hydraulic test. Only a few operators will be needed to control the equipment on this line.

Another thing that attracted me was a new material which is claimed to be harder than carbon steel and lighter than aluminium, and which does not soften at temperatures up to 1,400 deg. C. This material is almost certainly a ceramic, since it is known that Soviet scientists have made ceramic magnets from compressed iron and barium oxide powders (the pressed mass is baked in an electric furnace and then placed in a magnetic field, where it acquires the properties of a permanent magnet). The object of producing magnets of this type is to save the cost of expensive alloys such as those of nickel and cobalt, which are widely used in making permanent magnets.

The Soviets are very interested in the physics of high pressures, and recently they have introduced a method of producing parts by liquid pressure in which the nozzle of a hydraulic installation shoots out brand-new metal parts. In this process, a high-powered compressor forces fresh doses of liquid into a vessel containing a blank which closes up the nozzle from the inside as if it were a cork. The pressure is then increased to several thousand atmospheres, and the metal forces its way out through the narrow opening of the nozzle enveloped in a thin layer of the ejecting liquid. It is, therefore, encased in what might almost be termed an elastic and unusually strong film. Soviet scientists have developed a unique installation for producing high pressures continuously, as a boiler produces heat, and it is this installation that produces the parts referred to above. The liquid film covering the parts prevents wear and tear of the nozzle by the extruded metal, and also saves energy. To press a metal with a steel piston requires about 3 t.s.i.—liquid needs only 0·7 t.s.i. for the same work. A wide range of different parts are to be produced by liquid pressure when the successful experiments of the designers have been translated into practice by industry.

One of the items I examined was a machine which gives a detailed picture of the new electric erosion method of working metals. This method is finding ever wider application in the production of intricately formed parts, and has spread to the West, where the techniques have been improved. I saw also how ultrasonics are being applied extensively to the building of machines. In particular, the Russians are using it for boring holes of all shapes in hard and brittle materials, for blasting and degreasing, and for soldering aluminium. The machines demonstrating the use of ultrasonic broaching were of several types, with 100 watt to 10 kW generators, and automatic installations for blasting and degreasing.

Specially interesting to me was a tractor-type automatic flux-welding machine regulated by a three-phase arc. Electric slag welding is becoming widespread in the production of big machines. The most interesting of these devices was an



A high-pressure machine nozzle is shown extruding metal rod, from which gears (inset) can be sliced.

installation fitted with a lamellar electrode universal apparatus capable of welding articles up to 1,600 mm. thick. The same method underlies the work of a magnetic-walking automatic machine which welds vertical metal corner seams of a thickness up to 80 mm. Electric slag titanium welding is another development. Carbon-dioxide welding apparatus was of great variety, and included new kinds of semi-automatic installations and various welding burners. There was a machine for automatically coating worn dies and metal-cutting tools in a bed of ceramic flux, as well as for coating the journals of shafts with a film of bronze, etc.

In the instrument field, I was able to see some extremely interesting unique flowmeters, such as a magnetic rotameter, an induction flowmeter, an ultrasonic flow meter, and other instruments for controlling and regulating the flow of gases and liquids.

The Russians are paying increasing attention to the use of rare metals for the manufacture of small industrial parts. Among the metals so used are germanium, rhenium, silicon, zirconiun, tantalum, gallium and thallium. The Soviets are also fully acquainted with the use of hard alloys and ceramic materials for metal cutting tools.

In the machine tool field, apart from the plastic lathe earlier mentioned, I saw a six-cylinder upright hydraulic automatic turning lathe fitted with hydrocopying supports. Another powerful machine was a new radial drill capable of drilling holes of up to 75 mm. dia. Yet another impressive machine was a highly productive automatic balancing machine fitted with electronic controls. This was in essence a set of three lathes, one of the balancing type and the other two for drilling. That the Russians are rapidly catching up with the West was exemplified by the milling machines fitted with pre-set controls, and designed to work complicated details. The programme for these is pre-set directly from the blueprint, or from the mathematical expression.

The Soviets are by no means behindhand in thermal treatment plant, as is exemplified by their vortex cooling installation, which cools metals down to a temperature of −60 deg. C. and which is based on the effect produced by fast whirling cold and hot streams. They also have a continuous action gas cementation unit, in which the processes of cementation or case-carburizing, tempering and quenching follow one another in continuous succession. The stability of this process is ensured by a series of control devices.

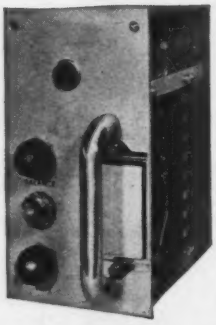
Many of the machines mentioned above were prototypes, and it was not certain that they were all in production. Nevertheless, it would be wrong to imagine that they are showpieces with no reality behind them. The Russians do not believe in wasting time and materials merely for propaganda purposes, and these machines are either working on important jobs or they soon will be. The one unshakable fact is that during the thirty years that have elapsed since my last visit, the U.S.S.R. has changed out of all recognition.

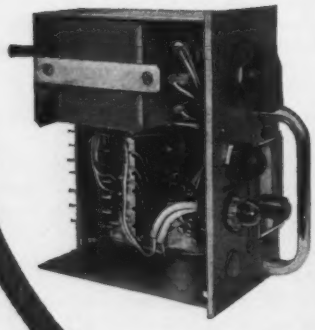
GLASS CERAMICS FOR BALL TRACES

PROBLEMS of mechanical strength, dimensional stability and corrosion resistance preclude the use of metallic alloys for rolling-contact bearings at ambient temperatures much above 540 deg. C. Hot hardness, an important property of rolling-contact bearing materials, rapidly falls below acceptable values in this temperature range. To meet the increasing need for bearing applications at temperatures above the limits of alloy steels, ceramics are now being considered as bearing element materials.

For applications in the temperature range extending several hundred degrees above the limits of metallic alloys, crystallised glass ceramics offer promise. While they do not have the high strength and ductility of alloy steels, crystallised glass ceramics retain their strength, hot hardness and corrosion resistance up to high temperatures. Low thermal expansion coefficients permit control of bearing clearances over a wide range, from room to operating temperature.

An important consideration in very high temperature bearing application design is lubrication and wear. Adequate lubricants have not yet been developed for temperatures in the range where the properties of crystallised glass ceramics make their use advantageous. Preliminary unlubricated tests by the Lewis Research Center, U.S.A., show that severe wear precludes runs long enough to produce fatigue failure. This indicates the necessity for some form of lubrication in a study of the fatigue life of glass ceramics. Very high temperature bearing development may depend upon the availability of adequate lubricants as well as materials, and both solid and reactive gas lubricants show promise of meeting this need.





EMIAC II

an infinite range of analogue computers

For its price, EMIAC II is easily the most versatile analogue computer available today. It enables the smallest user to order a "one off" computer at a mass produced price, whilst the largest organisation can obtain a general purpose computer or a special simulator of any desired size and characteristics. In every case the user buys only what he needs and receives no redundant equipment. How is this done?

'C' Box is the secret

In EMIAC II the same small range of standard amplifiers will add, integrate, multiply, divide, reverse polarity or generate a function. All needed changes are made by the 'C' Box which makes the appropriate connections to the Patch Panel, arranges the corresponding switching and contains the components required for the particular computation. A range of eight 'C' Boxes covers the most frequently used functions. They are readily interchangeable and plug conveniently into the front of the computer. Reserve 'C' Boxes can, of course, be held to extend the computer's versatility. Their small size presents no storage problems.

The right computer for you

We invite you to let us know your special requirements for an analogue computer. We then suggest the ideal equipment for the purpose, together with any reserve components for secondary applications. Finally we assemble the equipment ready for use. We will be glad to demonstrate the computer and discuss your particular problems.
Full literature on EMIAC II is available.

On the left, an engineer removes a 'C' Box, two typical examples of which are shown.

E.M.I. ELECTRONICS LTD

CONTINUOUS PROCESS CONTROL DIVISION
HAYES, MIDDLESEX. TEL: SOUTHALL 2468

EMI

EE 34

OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Rocket Sled

Aerojet-General Corp. have completed preliminary designs of a rocket sled which, together with a newly developed controllable thrust liquid rocket engine, promises to be one of the world's most advanced missile research testing vehicles. One of the most important test objectives is the calibration of a missile guidance system at a constant acceleration, and to attain this constant acceleration the engine must be capable of a variable thrust. The test vehicle will also be used for testing pilot ejection systems and missile and aircraft components. The sled is designed to accelerate a 3,000-lb. payload to over mach 2·0, and decelerate at a negative rate up to 20 g. The payload may be pushed in a separate sled or carried within a nose section joined to the power plant, as shown below.

Four longitudinal tanks containing the pressurising gas for expelling the liquid propellents also serve as the main structural members. Another innovation in the sled's design is the elastic suspension of two propellant tanks between the four longitudinal gas pressure tanks by a system of high-strength steel bands. This form of support permits a simpler design for the tanks, and eliminates undesirable external lugs and rails. The sled structure will be provided with an aerodynamic fairing to reduce air resistance and drag.

The XLR-113-AJ-1 lightweight controllable thrust engine, developed for the U.S. Air Force, has a film-cooled thrust chamber, a start and restart capability and a controllable thrust range from 50,000-150,000 lb. A special injector provides the proper mixture of propellant to give the engine a stable thrust over a wide range, and is controlled by varying the electrical current through an electro-hydraulic valve system to the thrust control valve. A change of 8 mA. in current is sufficient to provide the alteration in thrust over the controllable range.

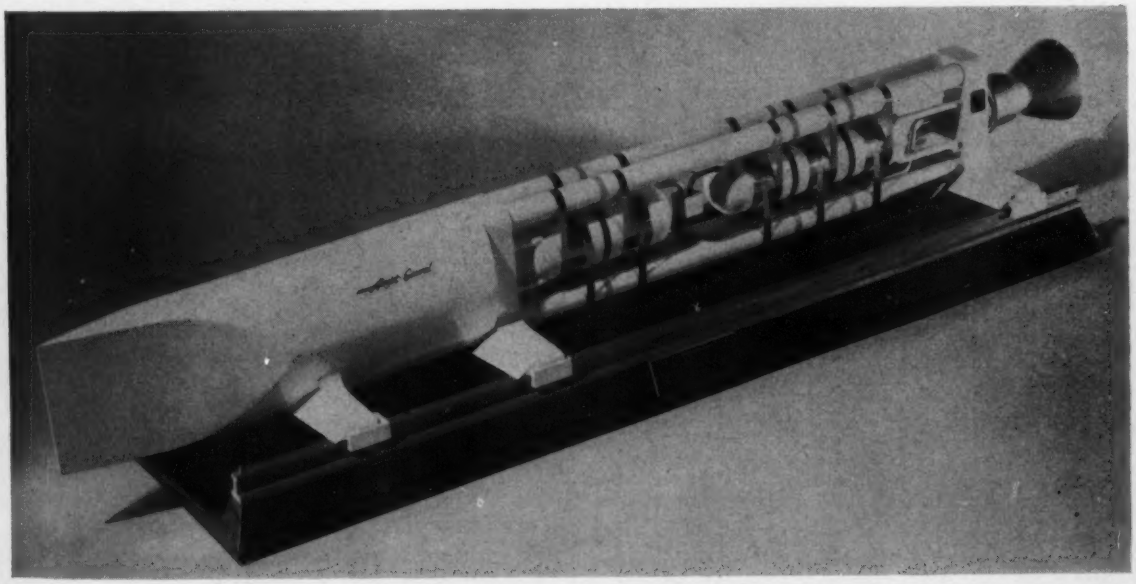
Induction Pumps for Molten Metal

Electromagnetic pumps can be used to circulate molten-metal coolants in certain types of nuclear reactor. The flat-linear type of induction pump shows great promise, due to the simplicity of its construction and its ability to draw power from conventional three-phase power lines. With this type of pump the three-phase winding on the stator core creates a travelling magnetic field, which induces current in the molten metal placed in a gap between the cores. The flow of molten metal along the longitudinal axis is caused by the interaction of the travelling field and the induced current.

At the Physics Institute of the Latvian Academy of Sciences, a series of studies on the theory and practice of electromagnetic induction pumps is being carried out under the direction of I. M. Kirko and I. A. Tyutin, with substantial contributions by A. I. Vol'dek. A considerable number of problems relating to the performance of induction pumps are still unsolved, among these being the interaction of transverse and longitudinal fringe effects, the demagnetizing effect of the current in the metal on power loss and pressure drop in the pump, and determination of the equivalent parameters of the secondary circuit.

New-type Fuel Pump

The design of the German DKW two-stroke engine is based on the principle of using as few moving parts as possible. In this engine the conventional diaphragm type of fuel pump operated by a cam via a push-rod or bell crank has been eliminated. In the new design the pump diaphragm is actuated by the pressure created in the crankcase during the compression stroke, and by the vacuum created during the suction stroke of the piston, thus causing the pump to deliver fuel from the fuel tank to the carburetter.



New Books

A Course of Reinforced Concrete Design. *Third edition by Thomas J. Bray. (Chapman & Hall—63s.)*

First published in 1946, this book has rightly been regarded by non-mathematical students and young structural engineers as one of the simplest, and therefore one of the most useful introductions to reinforced concrete design.

By comparison with earlier editions, the third edition has been completely rearranged, and much of it has been rewritten and slightly expanded. There are now fifty-one design charts, and they are placed near their explanatory text, which is an improvement. There are three important but brief chapters added on hollow-block floors, high yield-point steel and load-factor design.

The elastic theory of reinforced concrete design is the generally accepted theory, and is known to be safe. Where the concrete is of a uniformly high standard, load-factor design may be allowed, and will enable economies to be made either in steel or in concrete, or both. The justification for load-factor design is that tests to destruction of many concrete members have shown that the compressive stresses adjust themselves to give a greater total compression than that calculated by the elastic theory.

Two assumptions of the elastic theory rendered unnecessary by load-factor design are: (a) there is no need to assume a constant ratio between Young's modulus in steel and Young's modulus in concrete (usually taken as 15 in elastic design), and (b) there is also no need to assume, as in the ordinary theory of bending, that there is a linear relationship in the concrete between stress and strain.

Prestressed concrete is introduced in two pages, but quite rightly no attempt is made to discuss it in detail. It is a different subject from reinforced concrete (though developed from it), using different steel, concrete of higher grade and a different basis of design.

No important subject covered in the earlier editions seems to have been omitted, and the author's thorough revision of the book should make it useful to the experienced designer, without loss of the clarity of the earlier editions. The calculations are now in accordance with the current British Standard Code of Practice for reinforced concrete, BSCP 114.

John S. Scott

Surface Effects on Spacecraft Materials. *(John Wiley; Chapman & Hall—92s.)*

This volume includes papers and discussions presented during the first symposium of surface effects on spacecraft materials, held under the co-sponsorship of the United States Air Force and the Lockheed Aircraft Corp. Papers which may be regarded as particularly interesting are: "Coatings for Space Vehicles", "Emissivity of Materials near Room Temperature", "Vacuum Volatility of Organic Coatings" and "Effects of High Vacuum on Mechanical Properties".

Mathematical Methods for Digital Computers. *By A. Ralston. (John Wiley; Chapman & Hall—72s.)*

This work is a collection of articles on numerical methods, by authors who have almost all made significant contributions to the subject; each article deals with one specific method, chosen for its usefulness or interest on automatic digital computors. It is not meant to be a treatise on numerical analysis for the general user, but is oriented wholly to the requirements of users of digital computers. The topics of the articles range over subjects in linear algebra, ordinary and partial differential equations, statistics and miscellaneous other subjects, including the solution of polynomial equations, linear programming and various applications of Monte Carlo methods.

The book contains twenty-six chapters, each of which considers one numerical method. The chapters follow a common format; first there is a discussion of the nature of the problem and of the mathematical principles involved in its numerical solution. This is followed by sections of particular interest to users of digital computers. The theoretical method is broken down into a step-by-step computing procedure which is illustrated with a flow diagram and a sample problem. Each chapter ends with an estimate of the storage requirements and of the running time.

This book is unique in its field and should be valuable to users of scientific computers.

Temperature Measurement and Control. *By W. F. Coxon. (Heywood & Co. Ltd.—60s net.)*

This volume, the fifth in a series of technological text-books published on the physical processes in the chemical industry, will be of great value to students and apprentices specialising in this particular field of engineering.

The complete study of temperature and its effects is well covered. Commencing with preliminary data on heat, it continues with fundamental data for temperature measurement, and quotes the classification and choice of temperature measurement methods using the various thermometers, thermocouples, electronic potentiometers and radiation pyrometers. Later chapters enlarge upon these instruments. Additional information is also given on the measurement of high temperatures, and the automatic control of temperatures by valve and damper regulators.

The book is well illustrated with many self-explanatory diagrams, and thoroughly covers both the theoretical and practical side of the subject. It is written in an easy-to-follow style and discusses many of the problems encountered, enabling the reader to reason out for himself the problem at hand. This book could become a classic in this branch of engineering technology.

F. Smith

Engineering Data Processing System Design. *By Arthur D. Even. (D. Van Norstrand Co. Ltd.—49s.)*

This book, written by one of America's leading authorities on the use of combined microfilm punched-card techniques, clearly outlines the problems of engineering data movement and suggests ways in which these problems can be resolved.

The book is of interest to engineering systems men and data processing men alike. The former will identify their own problems and appreciate the logical solutions put forward. For data processing men, the field of engineering document control is a new one, and Mr. Even has gathered and consolidated for them the hitherto scattered theory of mechanised high-volume engineering drawing control.

The functions of "Drawing", "Engineering Orders", "Engineering Notices", "Engineering Parts List", "Engineering Change Notice", "Engineering Release Notice" and the "Parts Usage" or "Usage Location Index" are all discussed. These listings and drawings exist in some form or other in all engineering enterprises, and Mr. Even has in the early part of his book shown how order can replace the chaos often found in engineering departments where documentation has been regarded as an evil, and has therefore never been properly administered.

The section on gaining management approval for engineering document mechanisation is remarkably well tackled. The preparation of a "justification" is discussed at length, and is a very valuable part of this publication.

The problems of installing, operating and controlling the system are discussed, and examples are drawn from the author's personal experience. The use of flow charts greatly assists the understanding of the text, and the different machine types required in any mechanisation programme are discussed and backed up by photographs or schematics. The glossary of terms is most helpful.

The author, obviously aware of the rate of change evident in the electronic data handling field, has very wisely commented on future prospects. Microfilm images on magnetic tape and large random access storages, he suggests, may bring engineering drawing control squarely within the realms of ordinary data processing, and no longer will the drawing claim a realm of its own, as it most certainly does today.

N. R. Blatch

Powder Metallurgy No. 5. *(The Iron and Steel Institute and the Institute of Metals; a bi-annual publication at 10s. per annum to members and 25s. to non-members.)*

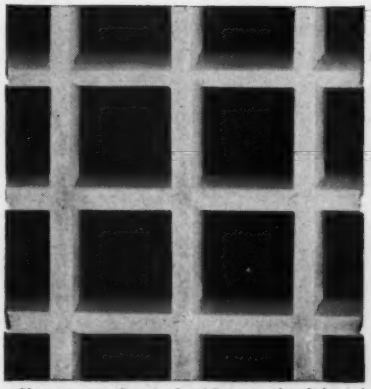
This publication includes papers on metal/ceramic mixtures, sintered stainless steels, textures in beryllium rods and tubes, and printed discussions on the powder metallurgy of magnetic materials, given at a previous meeting of the powder metallurgy group.

for heat resistance

special "thin-flash" type for grille moulding

Beetle D.M.C. is the material used for the grille of the Morphy-Richards Fan Heater because it offers high heat resistance and good appearance. The use of D.M.C. posed a flash-removal problem in relation to the many apertures, as the moulders, Crystalate (Mouldings) Ltd., specified a very thin flash line. Accordingly, B.I.P. Chemicals Ltd. developed a special type of material (D.M.C. L.1834) which, in combination with a tool made to close limits, ensures a consistently thin and easily removed flash.

Beetle D.M.C. combines heat resistance with strength, dimensional stability and excellent insulation properties. The development of a special type for a single application typifies the extent of B.I.P. services in relation to individual problems and requirements.



Heat resistance, dimensional stability, strength and electrical insulation properties are among the features making D.M.C. the ideal material for this grille. Moulding by Crystalate (Mouldings) Ltd, Tonbridge, Kent.

BEETLE*

Polyester dough moulding compound

B.I.P. Chemicals Limited, Oldbury, Birmingham. Phone BROadwell 2061
London Office: Haymarket House, 28 Haymarket, S.W.1. Phone TRAfalgar 3121

New Books (Cont. from page 708)

Engineering Design with Rubber. *By Payne and Scott.* (*Maclaren & Sons Ltd.—50s.*)

Here at last is a book that will greatly aid engineers and students with problems associated with rubber. It is one of the first publications dealing in such a manner with this subject, and originates from a symposium held in 1958; the interest shown indicated the need for a practical manual.

Subjects dealt with include the various stressing problems which occur in rubber (comparing these with similar cases in metals), and the effects of vibration and shock (illustrating how these are related to both temperature and frequency of deformation). There are also chapters devoted to creep and its recovery, and the relationship between force and deformation, resonance and transmissibility. Thermal and electrical properties, and the effects of oil and ageing, are also explained. All test methods, both dynamic and those other than dynamic, are fully covered in both theoretical and practical aspects where these have been found necessary.

This book gives a wealth of information and useful design hints, such as how to avoid high areas of stress, and general applications in engineering. It is extremely well illustrated, and written in a manner which is both easy to follow and clear to understand. Many instructive graphs, diagrams and photographs are included, and an Appendix gives British and American tests and standards for both synthetic and natural rubber.

Adhesive Bonding of Reinforced Plastics. *By H. A. Perry.* (*McGraw-Hill—68s.*)

This book serves all those interested in the design and assembly of structure and products by means of adhesive, particularly the manufacturer of glass fibre reinforced products. It provides all the available useful information in this field, including recent advances in the theory of the mechanics of adhesive joints. The various chapters cover the types, properties and design of adhesives; the quality, reliability and design of suitable joints, and the equipment necessary for such operations.

Mechanism. *Fifth edition, by V. M. Faires and R. M. Keown.* (*McGraw-Hill Book Co.—58s.*)

Established as an American classic for mechanical engineering students, the fifth edition of this book has been revised to incorporate the numerous technical developments in this field since the first publication in 1939.

Details covered include the basic explanation of equations of plane motion such as kinematics, acceleration, velocity ratio, harmonic and curvilinear motion. There is an instructive chapter on cams, covering the principle of jerk, cycloidal motion, methods of computing the pressure angle (with an explanation of the Geneva mechanism design), and general hints for design improvement. Design information is given in great detail for spur, helical, bevel and worm gears, with a full coverage of gear trains. Other miscellaneous devices such as ratchets and universal joints are also included, and well illustrated.

This book is intended primarily as a working text, and is written in a clear, easy-to-follow manner with logical explanations covering the more practical problems of motion in engineering. At the end of each chapter problems have been set, although answers are not supplied. An appendix is also included, giving many suggestions and tables, and laying out methods to be adopted for drawing various components. *F. Smith*

British Instruments. (*The Scientific Instrument Manufacturers Association of Great Britain—45s.*)

This directory and guide is a most comprehensive and valuable publication. In addition to a classified list of instruments and components there is also a French, German and Spanish glossary. Manufacturers are alphabetically listed (together with their overseas agents), and many of them have well-illustrated reference sheets giving details of their products.

Manual of Man-made Fibres. *By C. Z. Carroll-Porczynski.* (*Astex Publishing Co.—29s.*)

As the author states in his preface, the rate of growth of technology relating to man-made fibres is truly phenomenal, and it is possible today to produce a fibre with properties made to suit a particular end use. Thus this book makes a timely appearance, since for a modest price it contains a wealth of information which is not to be found in any other single publication.

The manufacturer, identification and properties are given in detail for each type of fibre, and a comprehensive bibliography forms one of the ten parts into which the book is divided. Chief of the remaining parts are those dealing with natural polymer man-made fibres, synthetic polymer man-made fibres, inorganic fibres, and textural yarns. Photomicrographs and x-ray diffraction photographs are well reproduced.

This is a reference book which, by the excellence of its layout and contents, can be recommended to designers and engineers in all branches of engineering.

OTHER BOOKS RECEIVED

Control of Steel Construction to avoid Brittle Failure. (*McGraw-Hill—35s.*)

Practical design manual prepared by the Plasticity Committee of the Welding Research Council (U.S.A.).

Metallising of Plastics. *By Harold Narcus.* (*Reinhold; Chapman & Hall—44s.*)

Detailed instructions for commercially metallising plastics and non-conductors.

Proceedings of Symposium on Microminiaturisation of Electronic Assemblies. *By E. Horsey.* (*Reinhold; Chapman & Hall—88s.*)

1958 Symposium sponsored by the Diamond Ordnance Fuze Laboratories (U.S.A.).

Metals Testing in the United States. (*E.P.A., O.E.E.C. publication—14s. 6d.*)

Survey of methods and equipment by an international mission.

Classified List of Equipment and Services. (*Council of British Manufacturers of Petroleum Equipment—10s.*)

Electron Metallography. (*A.S.T.M. special technical publication No. 262—$4.25; members, $3.40.*)

BS 3228, Part 1: 1960. (*British Standards Institution—3s.*)

Procedures for obtaining properties of steel at elevated temperatures.

BS 3252: 1960. (*British Standards Institution—4s.*)

Covering the chemical composition of three grades of ingot tin, together with other general requirements relating to inspection and testing.

BS 3253: 1960. (*British Standards Institution—6s.*)

Phenolic-resin bonded asbestos-paper sheets for electrical insulation at power frequencies.

BS 3255: 1960. (*British Standards Institution—6s.*)

Presspaper for electrical purposes.

BS 173: 1960. (*British Standards Institution—10s.*)

Specifications for rotating electrical machines for use on road and rail vehicles.

BS 1706: 1960. (*British Standards Institution—5s.*)

Specifications for electroplated coatings of cadmium and zinc on iron and steel.

BS 3249: 1960. (*British Standards Institution—5s.*)

Specifications for cables and flexible cords insulated with varnished cambric and heat-resisting fibre.

BS 903, Part A17: 1960. (*British Standards Institution—4s.*)

Determination of the permeability of rubber to gases, giving details of the test piece, procedure and calculation of results.

BS 3238, Part 1: 1960. (*British Standards Institution—4s. 6d.*)

Graphical symbols for diagrams containing transductors and magnetic amplifiers.

BS 3258: 1960. (*British Standards Institution—5s.*)

Silicone-rubber-insulated cables and flexible cords.

LETTERS TO THE EDITOR

Sir,

The following outline of the course leading to a Diploma in Engineering Design (Dip.Mech.Des. and Dip.Mech. Des. (Hons.)), and the reasons for its proposal, which were debated at a recent meeting of the Institution of Engineering Designers, may be of interest to your readers.

There is a growing realisation that design (in its widest sense, encompassing mathematical analyses, theory of machines, strength of materials, appearance, proportion, practicability, manufacture and detailing) cannot be "taught" to the student at university or technical college. It seems that "mature" design is the result of one's own experience as a "designer" coupled with the acquisition of the ability to "build-up" a project where there is little precedent.

Since it is difficult to teach the younger student the art of mature design when he has little industrial experience, the proposal makes it clear that the Diploma is offered only to those who already have some design experience in industry, coupled with academic qualifications up to H.N.C. standard or above.

The aim of the course and Diploma is to: (1) stimulate the candidate's creative ability (to steer him to invention rather than modification); (2) to enable him to undertake further research into his chosen profession; (3) to provide a qualification for the more responsible posts in design; and (4) to provide a qualification of a high standard which is recognised as a proof of creative design ability.

Although the proposal is in its early stages, and needs further inquiry and programming, the following broad principles have been put forward:

1. The scope of each course should be limited to a specialised aspect of design (i.e., mechanical, structural, electrical, marine, aeronautical, naval, etc.) with a separate syllabus for each course, and a Diploma to distinguish the course completed by the candidate, such as Dip. Mech.Des., Dip.Struct.Des., etc.

2. A candidate would be able to enter for more than one Diploma, though at different examinations.

3. In the early stages it is anticipated that only the mechanical course would be available. Other courses could be programmed after a proving period with the Mech. course.

4. The course might consist of a series of design projects, starting with the simpler unit designs and working up to complex projects of examination standard. (Many senior designers may not require to take the course, but could prepare themselves, making use of the syllabus, should they wish to attempt the examination.)

5. Each project would be completed by the candidate according to his own ideas with appropriate reference where necessary). These projects could be carried out at home so that the candidate set his own pace. The application of academic knowledge would be encouraged at every stage of these preparatory studies.

6. On completion of each project design study, it would be returned, together with mathematical analyses and relevant written work, to the board of examiners. The board would return written criticism and/or appreciation of the solution, together with course marks. Since "Design" is a form of "Art", you cannot teach the subject, but have to rely on criticism of the completed work as a means of instruction. This is the accepted form of teaching "Arts", which may also be considered as a form of "concentrated experience" in our present context. In the old days, the "senior designer" took the place of the "board" of examiners, and guided the younger members of the design office. Unfortunately, in industry, the senior designer seldom has time to spare these days.

7. On completion of the full course of studies, the candidate would then sit an external examination, set by the board of examiners in conjunction with the Institution of Engineering Designers, and held in convenient national centres once or twice a year. The examination would be in the form of a complete design project, and would require a time of possibly 35 hours (5 days of 7 hours per day) in order to complete a working scheme from a given specification. General drawing office standards would have to be provided, together with details of any proprietary units which may be specified for incorporation in the design (gearboxes, clutches and the like). No other notes would be allowed. A limited choice of projects is envisaged.

8. The completed schemes would be handed in, together with written work (description of design principles, typical calculations, etc.). These would then go before the board of examiners for assessment. The board would include representatives of academic, practical and commercial aspects of design, and each would award a percentage for a particular facet of the design. Specialists would be called on if required.

9. The candidate would then be (a) informed of the assessors' marking, and (b) instructed to proceed with Parts 2 and 3 of the examination, *or* instructed to proceed with Parts 2 and 3 (Honours), *or*, in the event of failure, instructed not to proceed.

10. Part 2 is the complete detailing of all the components of the project, or such parts of it that the examiners consider sufficient to show the practicability of the design. The scheme would be returned to the candidate for this purpose, and he would be given a time limit of say three to six months to complete the work at home.

11. Part 3 is a thesis of approximately 5,000 words, which should lay out the factors influencing the choice of methods, typical mathematical analyses, choice of materials, proposed method of manufacture and assembly and precautions, etc., etc. Only slight modification of the original examination design would be acceptable, provided it was covered by a written note.

12. Part 4, at the discretion of the examiners, would be an oral examination.

13. Passes would be required in all parts of the examination.

14. An overall percentage of 60 would gain the Diploma of Design in the particular branch of engineering (Dip.Mech. Des.).

15. Over 80 per cent would gain the Diploma of Design (Honours) (Dip. Mech. Des. (Hons.)).

16. A small annual retaining fee would be payable for holding the qualification, to maintain the courses, and for entering the holder's name in a "Register of Professional Designers". Entrance qualification would be Corporate Membership of the Institution of Engineering Designers, and the Diploma would only be retained so long as the holder remained a member of the I.E.D.

The above proposals may be of interest to designers and engineers, who may also like to add their comments and criticisms through your journal.

Wm. A. A. Witham

4 Kennel Lane,
Bracknell,
Berks.

Sir,

Referring to Problems in Design No. 8 series and in particular to my solution—Fig. 5 (p. 545, September)—may I point out that its apparent elaboration is brought about by the exigencies of the set problem, in that the output shaft had to rotate in the same direction as the input shaft.

The hypocycloidal gear must include a reversing gear to achieve this requirement. Some have chosen to ignore the requirement, others have introduced a bevel gear. Solutions not using a hypocycloid have resorted to chains and sprockets on floating centres or slides, which in my opinion do not make for precise mechanisms.

The only concession I made to compactness was to use an up-and-down gear, 2:1, 1:2 ratio, to achieve deliberately a common operation in cutting two internal gears together. The input drive is strong and rugged and well held on its encompassing bearings.

The hypocycloid is not duplicated as stated in your comments: the confusion may have arisen by the deliberate choice of common sized internally cut gears.

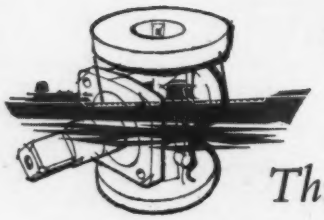
The hypocycloid gear is an elegant method of obtaining straight-line motion and lends itself to kinematic design principles. The fact that the problem was bedevilled by the output shaft rotation being altered from the natural way made it the more interesting.

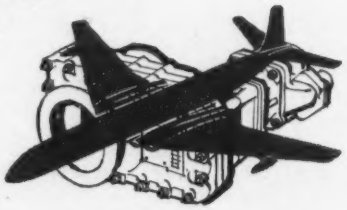
J. Tindale

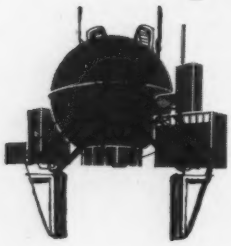
Elliot Bros. (London) Ltd.,
Century Works,
Lewisham, London, S.E.13.

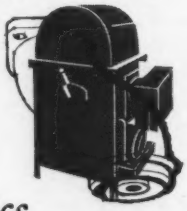
Our apologies to Mr. Tindale. Although two internally cut gears are used, only the output drive is hypocycloidal. The input reversal gear is not hypocycloidal, as the driven pinion is fixed and does not rotate about the axis of the internal gear.

Kanigen *a hard, non-porous corrosion-resistant plate, gives complete uniform coverage even to the most intricately shaped parts. Thickness can be controlled to fine limits. Being chemically deposited Kanigen can be applied to practically all metals in commercial use. It can also be applied to non-conductors such as plastics and ceramics.*









KANIGEN
ALBRIGHT & WILSON

Approved under DTD 900/4505 and ARB A1/5112/57. Already widely used throughout industry including aircraft and nuclear applications. Kanigen is the registered trade mark of Albright & Wilson (Mfg) Ltd.

For full information write to:

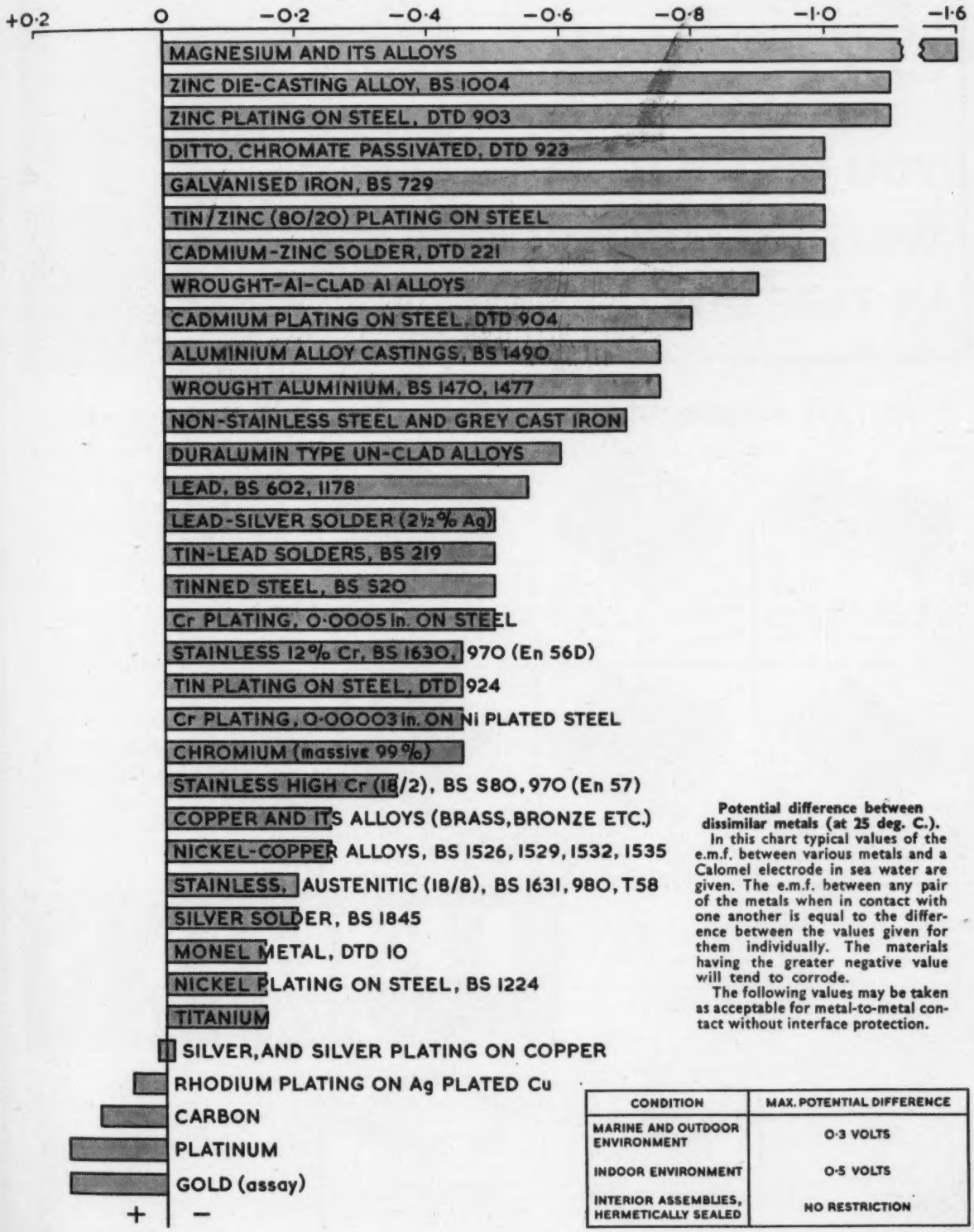
ALBRIGHT & WILSON (MFG) LTD

Kanigen Department (EMD)

1 KNIGHTSBRIDGE GREEN · LONDON SW1 · TEL KENSINGTON 3422

Engineering Materials and Design

DATA SHEET No. 48


+0·2
0
−0·2
−0·4
−0·6
−0·8
−1·0
−1·6
MAGNESIUM AND ITS ALLOYS
ZINC DIE-CASTING ALLOY, BS 1004
ZINC PLATING ON STEEL, DTD 903
DITTO, CHROMATE PASSIVATED, DTD 923
GALVANISED IRON, BS 729
TIN/ZINC (80/20) PLATING ON STEEL
CADMIUM-ZINC SOLDER, DTD 221
WROUGHT-Al-CLAD Al ALLOYS
CADMIUM PLATING ON STEEL, DTD 904
ALUMINIUM ALLOY CASTINGS, BS 1490
WROUGHT ALUMINIUM, BS 1470, 1477
NON-STAINLESS STEEL AND GREY CAST IRON
DURALUMIN TYPE UN-CLAD ALLOYS
LEAD, BS 602, 1178
LEAD-SILVER SOLDER (2½% Ag)
TIN-LEAD SOLDERS, BS 219
TINNED STEEL, BS 520
Cr PLATING, 0·0005 in. ON STEEL
STAINLESS 12% Cr, BS 1630, 970 (En 56D)
TIN PLATING ON STEEL, DTD 924
Cr PLATING, 0·00003 in. ON Ni PLATED STEEL
CHROMIUM (massive 99%)
STAINLESS HIGH Cr (18/2), BS S80, 970 (En 57)
COPPER AND ITS ALLOYS (BRASS, BRONZE ETC.)
NICKEL-COPPER ALLOYS, BS 1526, 1529, 1532, 1535
STAINLESS, AUSTENITIC (18/8), BS 1631, 980, T58
SILVER SOLDER, BS 1845
MONEL METAL, DTD 10
NICKEL PLATING ON STEEL, BS 1224
TITANIUM
SILVER, AND SILVER PLATING ON COPPER
RHODIUM PLATING ON Ag PLATED Cu
CARBON
PLATINUM
GOLD (assay)
+
−

Potential difference between dissimilar metals (at 25 deg. C.).

In this chart typical values of the e.m.f. between various metals and a Calomel electrode in sea water are given. The e.m.f. between any pair of the metals when in contact with one another is equal to the difference between the values given for them individually. The materials having the greater negative value will tend to corrode.

The following values may be taken as acceptable for metal-to-metal contact without interface protection.

CONDITION	MAX. POTENTIAL DIFFERENCE
MARINE AND OUTDOOR ENVIRONMENT	0·3 VOLTS
INDOOR ENVIRONMENT	0·5 VOLTS
INTERIOR ASSEMBLIES, HERMETICALLY SEALED	NO RESTRICTION

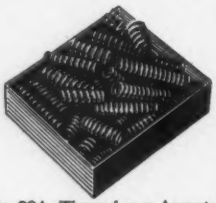
Data by S. Roberts, A.M.I.E.D.

THAT *Experimental Spring* YOU WANT IS WAITING FOR YOU IN THIS BOX...

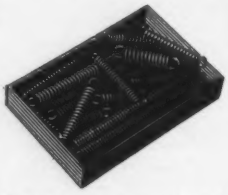
No. 1217. One gross Assorted Springs. A complete Garage Service Kit. 42/- each.

If not, try another box in the Terry Assorted Springs range

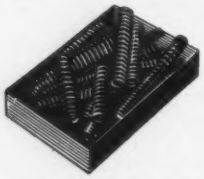
No. 1200. Three dozen Assorted Light Expansion Springs, suitable for carburettor control, etc. **13/6.**



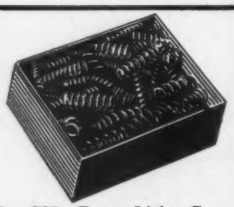
No. 98A. Three dozen Assorted 1″ to 4″ long, ¼″ to ¾″ diam., 19G to 15G. **5/6.**



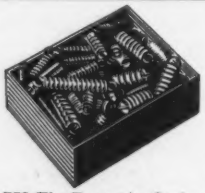
No. 753. Three dozen Assorted Light Expansion ¼″ to ½″ diam., 2″ to 6″ long, 22 to 18 S.W.G. **10/6.**



No. 760. Three dozen Assorted Light Compression Springs. 1″ to 4″ long, 22 to 18 S.W.G., ¼″ to ½″ diam. **6/6.**



No. 757. Extra Light Compression, 1 gross Assorted, ¼″ to $\frac{7}{16}$″ diam., ¼″ to 2¼″ long, 27 to 19 S.W.G. **15/-.**



No. 758. Fine Expansion Springs. 1 gross Assorted ¼″ to ⅜″ diam., ½″ to 2″ long, 27 to 20 S.W.G. **15/-.**

We know *exactly* how difficult it is to find springs for experimental work . . . we've been making quality springs for over 100 years. So, we confidently offer you our excellent range of small boxed assortments which covers a very wide range. We can only show a *few* boxes. Send us a p.c. for our full list. If ever you are stuck with a spring problem let our Research Department put their long experience at your disposal.

Have you a Presswork problem?

If so, the help of our Design Staff is yours for the asking.

TERRY'S *for SPRINGS*

Really interested in Springs? "Spring Design and Calculations" 9th Edition tells all—post free 12/6.

Cut Production Costs with Terry's Wire CIRCLIPS. We can supply immediately from stock—from ⅛″ to ⅝″.

Looking for good Hose Clips? Send for a sample of Terry's Security Worm Drive Hose Clip and price list.

HERBERT TERRY & SONS LTD

Redditch, Worcs.

(*Makers of Quality Springs, Wireforms and Presswork for over 100 years*)

HT30

Engineering Materials and Design

DATA SHEET No. 49

BURSTING STRENGTH OF TUBES AND CYLINDERS

The bursting strength of tubes and cylinders can be calculated on theoretical lines from the tube geometry and material strength, bearing in mind mechanical limitations which may arise from the construction of the tube or cylinder, the presence of stress raisers, surface finish and work hardening effects. In the case of hydraulic tubing, low carbon steels are generally preferred, the carbon content varying between 0·08 and 0·18 per cent, with 0·12 per cent carbon being about the optimum for maximum ductility (e.g., to permit flaring of the tubing).

The bursting strength of low carbon seamless tubing is commonly calculated on a maximum fibre stress of 50,000 p.s.i., and working strength assessed on a safety factor of 3·3, or 6·0 for heavy-duty applications. Deep polished seamless cylinder tubing will generally have an average ultimate tensile stress of the order of 80,000 p.s.i., due to the large amount of cold working during processing. With large D/T ratios, however, it may be necessary to stress-relieve the material in order to eliminate the possibility of distortion when machined.

All seamless metal tubes can be evaluated on a similar basis, using a safety factor of 3·0 (or higher, if desired). Plastic tubing is normally allocated a minimum safety factor of 5·0, and with such materials there are definite temperature limits for pressure tubing applications. Strength deteriorates rapidly with increasing temperature, and is effectively nil at the plastic point of the material. Tables 1 and 2 summarise typical mechanical data on tubing materials.

For analysis, tubing may be classified as "thin-walled" or "thick-walled", depending on the D/T ratio. Where the D/T ratio is 16:1 or greater the stress is basically tensional, and no bending or torsion is assumed; thus Barlow's formula applies:

$$S = \frac{PD}{2T}$$

For thick-walled tubing (D/T less than 16:1), stress distribution varies from a maximum at the bore to a minimum at the outer surface of the wall. The tube is subject to axial, radial and hoop stresses, all of which can be evaluated separately by the Lamé formulae:

$$S_r = P \cdot \frac{R_2^2}{R_1^2 - R_2^2}\left(\frac{R_1^2}{r^2} - 1\right)$$

$$S_h = P \cdot \frac{R_2^2}{R_1^2 - R_2^2}\left(\frac{R_1^2}{r^2} + 1\right)$$

$$S_a = P \cdot \frac{R_2^2}{R_1^2 - R_2^2}$$

where r is the radius of the element of the tube under consideration.

Depending on the design circumstances, the appropriate formula should be selected and used (i.e., appropriate to the most significant stress in a particular application).

Nomogram 1 gives complete solutions for tubes used as pressure tubes or cylinder barrels, starting at the top horizontal scales by inserting the appropriate values of D and T. From the D/T ratio read from this nomogram, the tube can be classified as "thin-walled" or "thick-walled" and the appropriate vertical nomogram applied. The left-hand nomogram gives maximum working pressure, based on Barlow's formula for a given maximum permissible material stress. The right-hand nomogram gives similar answers for thick-walled tubing, based on maximum shear strain energy. It should be noted that the appropriate vertical nomogram only applies to the classification of the tube by D/T ratio. Either nomogram can, however, be used for calculating the bursting pressure of the tubing by inserting maximum material stress values in place of permissible material stresses.

Nomogram 2 can be used further to investigate thin-walled tubing. The two outer scales (D and T) are connected to establish an appropriate point on the centre reference scale. Material tensile strength on the inner left-hand scale projected through this point then reads bursting pressure on the inner right-hand scale. It should be noted that the top section of the reference scale is invalid (i.e., D and T values locating on this length are outside the range of thin-walled tubing). An approximate indication of high (bursting) pressure values which come off the main scale is provided by the sub-scale, but solutions falling in this region should be calculated direct from Barlow's formula.

This nomogram can also be used to establish wall thickness for a given diameter and required bursting pressures, by connecting the pressure and material stress scales first and then finding the value of T associated with the given diameter D. A change of material specification can also be investigated on similar lines. In all cases, however, this nomogram is only valid as long as the reference point comes within the usable range.

For thick-walled tubing, Clavarino's formula is widely used for steel tubing, and may also be expanded to accommodate other materials. A summary of formulæ which may be used for estimating required wall thickness in thick-walled tubing is given in the following table:

Clavarino Steel tubes only	Clavarino All metal tubes	Lamé All thick-walled tubes
$\frac{D}{2}\left(\sqrt{\frac{35_p+P_w}{35_p-4P_w}}-1\right)$	$\frac{D}{2}\left(\sqrt{\frac{S_p+P_w(1-2\sigma)}{S_p-P_w(1+\sigma)}}-1\right)$	$\frac{D}{2}\left(\sqrt{\frac{S_p+P_w}{S-P}}-1\right)$

The required thickness of the cylinder ends can be established from nomogram 3, again referring to Table 3 for typical values of permissible material stress. Values of T obtained from the nomogram must be multiplied by the tube or cylinder diameter D to arrive at a final solution, i.e., the nomogram gives solutions for T for 1-in. dia. cylinders, and T is directly proportional to D.

If it is necessary to calculate the central deflection of a flat plate end under pressure load, this can be done by a separate formula. Similarly, formulæ may be used for the evaluation of stresses developed in cylinders subject to bending or combined bending and tensional loads. In the latter case, the optimum radius can be calculated, or minimum cross-section for simultaneous failure.

Table 1. Ultimate tensile stress of metallic tube materials

Material	U.T.S. (p.s.i.)
low carbon steel (hydraulic quality)	50–55,000
deep polished tubes (hydraulic quality)	80–85,000
tungum	60–65,000
high-duty steel	62–65,000
copper	see Table of permissible working stresses

Table 2. Ultimate tensile stress of plastic pressure tube materials

Material	U.T.S. (p.s.i.)*
Nylon—IA29 grade	5,500
—harder grades	up to 11,000
Polythene—normal	1,400–1,800
—high-strength	3,000–3,600
P.v.c.—rigid	6,000

* At 20° C.

Table 3. Typical permissible working stresses for tube materials and cylinder ends

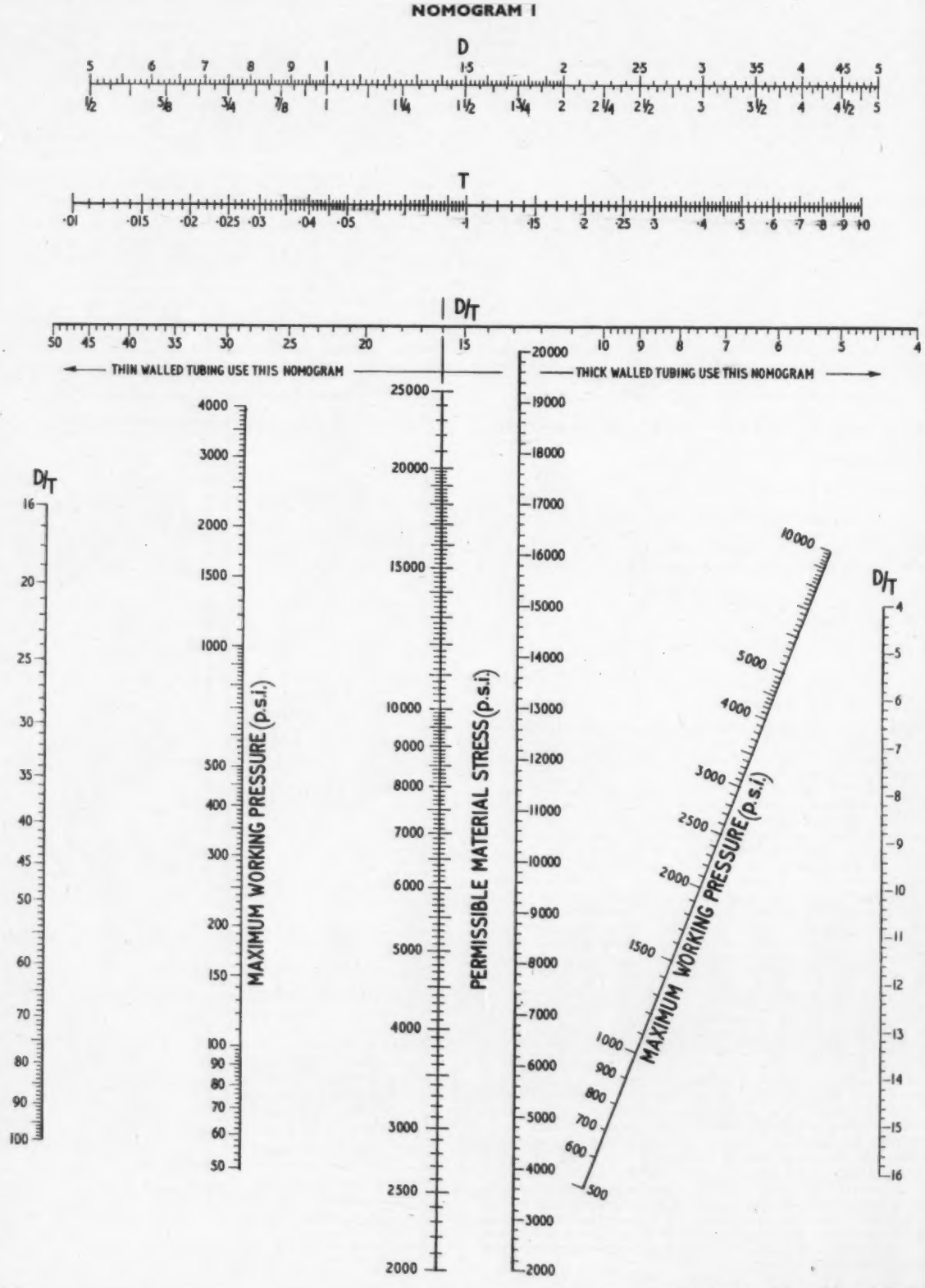
Material	Max. permissible stress (p.s.i.)
Low carbon steel	15,000
High-duty steel	20,000
Cast steel	12,000
Cast iron	4,000
Brass (average cast)	6,000
Red brass—up to 200°F.	8,000
300°F.	7,000
400°F.	3,000
Copper—up to 100°F.	6,000
200°F.	5,500
300°F.	4,750
400°F.	3,000

DEFINITION OF SYMBOLS AND UNITS

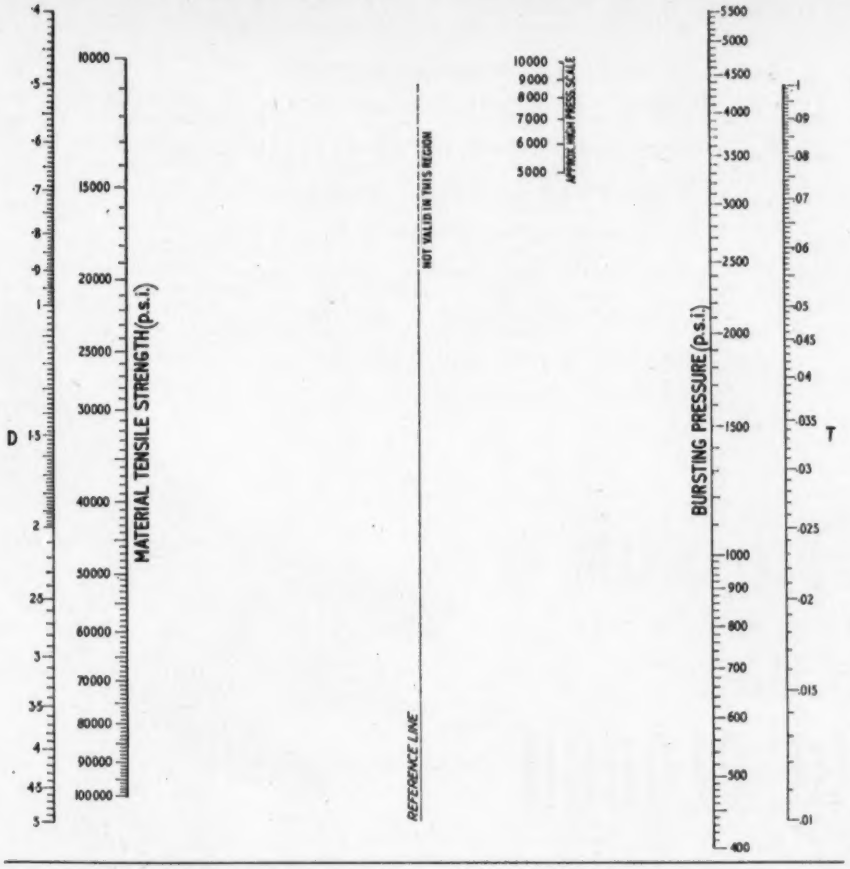
- S = stress (p.s.i.);
- S_p = permissible material stress (p.s.i.);
- S_a = axial tensile stress (tube with closed ends) (p.s.i.);
- S_r = radial compressive stress (p.s.i.);
- S_h = hoop tensile stress (p.s.i.);
- P = maximum pressure or pressure to induce failure (p.s.i.);
- P_w = working pressure (p.s.i.);
- R_1 = outer radius of tube (in.);
- R_2 = inner radius of tube (in.);
- D = overall diameter of tube (in.);
- T = thickness of tube wall (in.);
- σ = Poisson's ratio.

(*Continued overleaf*)

BURSTING STRENGTH OF TUBES AND CYLINDERS (Cont.)



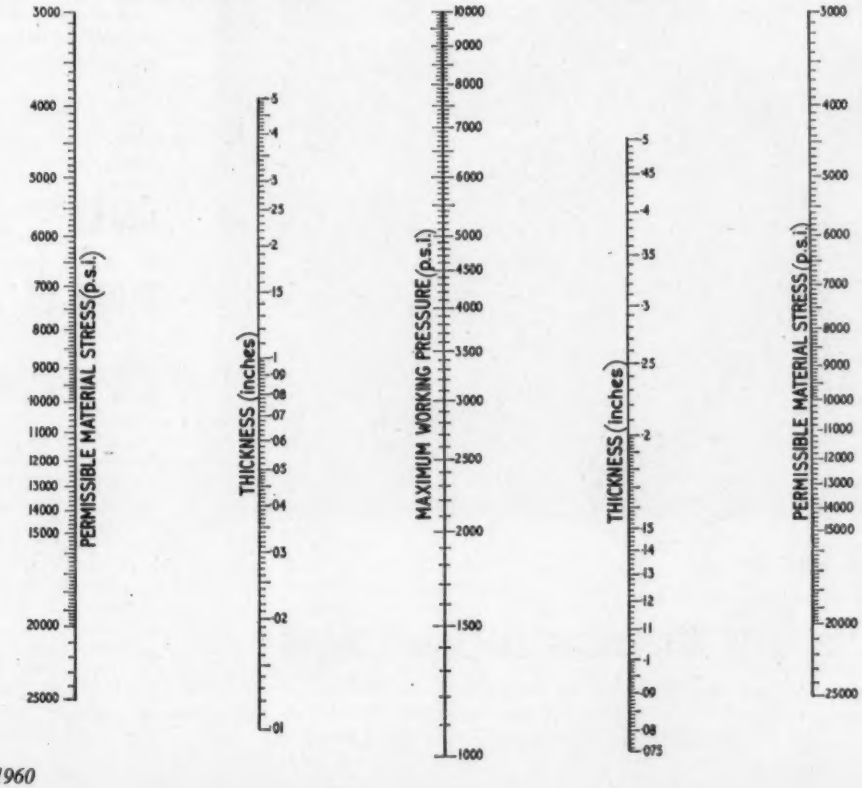
BURSTING STRENGTH OF TUBES AND CYLINDERS (Cont.)



NOMOGRAM 2

SPHERICAL ENDS

FLAT ENDS



NOMOGRAM 3

EMD 3997 for further information

Because the Rotaped half-track unit is shod with track links gravity die cast in lightweight magnesium, it can work without bogging down over soil too soft for a wheeled tractor. By halving and spreading the weight, the links also minimize soil compaction. The Rotaped operates in all conditions over every type of land. Magnesium alloy was chosen because it is strong and ultra-light. Like the Rotaped, it can take hard knocks and rough it in all weathers.

By courtesy of Sterling Metals Ltd.

MAGNESIUM SPEEDS THE PLOUGH

Information about the essential properties of MAGNESIUM, and advice on how this metal can best be converted into popular products, is always freely available from MEL—pioneers and sole producers of Magnesium in Great Britain.

make more of magnesium

Magnesium Elektron Limited

Clifton Junction Manchester Swinton 2511
London Office: 5 Charles II Street St. James's SW1 Trafalgar 1646
Magnesium Elektron, Inc., New York 20, USA

WHAT'S NEW IN MATERIALS & COMPONENTS

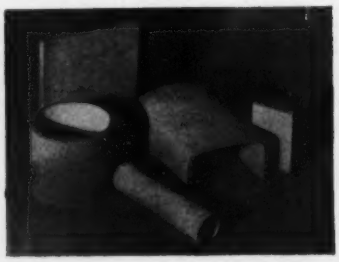
Rust Remover

Pitan rust remover is said to remove iron oxide by a mild complexing action which does not attack the molecular structure of the unrusted metal. The iron oxide is converted to a completely soluble form, thereby eliminating the necessity for removing residue from inaccessible places. All the ingredients used are claimed to be non-combustible and non-toxic. It contains no phosphoric or hydrochloric acid, and does not affect skin, clothing, gaskets, iron, brass, bronze or copper. Allweather Paints Ltd., 36 Gt. Queen Street, London, W.C.2.

EMD 4086 for further information

Electric Heating Elements

B.W. moulded electric heating elements provide a convenient and economic answer to many of the higher temperature heating problems which arise in experimental and prototype work. The variety of shapes which can be supplied enables temporary heating chambers and tunnels to be easily built up in the laboratory or research department, and special forms



can also be made for permanent installation in production equipment.

The elements are rigid self-supporting units manufactured under carefully controlled conditions by a technique developed after extensive experimental work and field tests. Two types are available—series E.1000 MHE to 1,000 deg C. and series E.1200 MHE to 1,200 deg. C. Barlow-Whitney Ltd., 2 Dorset Square, London, N.W.1.

EMD 4087 for further information

Flexible and Rigid Piping

Vacuflex hose is constructed of high-quality p.v.c., or other thermoplastics material, supported by a high tensile steel spring which is entirely covered in p.v.c. and which forms an integral part of the hose. Various grades are available according to application, varying from very flexible to rigid and employing a number of different plastics according to the degree of chemical resistance required. The tubing is available in nylon, p.v.c., high-density polythene and reinforced p.v.c. Applications are said to be extremely wide, including vacuum cleaners, hot air ducts, dust extraction, cable ducts, ventilation, and for conveying liquids or components to a moving platform or machine. Recon (Pipelines) Ltd., Sheerwater, Woking, Surrey.

EMD 4088 for further information

Arc-welding Electrode

A new arc-welding electrode, known as Opal 3½ Ni, has been developed for the welding of low-carbon 3½ per cent nickel and similar steels where good charpy impact values are required at sub-zero temperatures. This new electrode is designated E616 on the BS 1719 coding or E8016-C2 on the AWS-ASTM scale. The basic coating employed is said to give a clean weld metal, free from inclusions of slag and gases, in conjunction with easy, fast deposition characteristics in all welding positions.

Particular features are the stability of the arc and the ease of slag control, which enable d.c. and a.c. supplies down to 70 volts open circuit to be used. The mechanical properties of the electrode include a charpy impact value of 15-20 ft./lb. at −100 deg. C., a yield point of 27-31† t.s.i. and an ultimate tensile strength of 34-40 t.s.i. The carbon content is 0·5 -0·8 per cent, with silicon being 0·25-0·50 and manganese 0·4-0·8. Both sulphur and phosphorus are below 0·03 per cent each, and the nickel content is in the range 3·25-3·75. The electrode is produced in a range of five sizes, from 12 gauge to 4 gauge. Cooper & Turner Ltd., Vulcan Works, Vulcan Road, Sheffield, 9.

EMD 4089 for further information

Medium-impact P.V.C.

Geon RA.130, an unplasticised p.v.c compound, possesses good impact strength properties without the addition of a modifying material. It is designed for use in all profile extrusions and for most pipe applications, and is claimed to be tougher than other medium-impact unplasticised p.v.c. compounds; for example, pipe of 1·06 in. o.d. and 0·85 in. i.d. extruded from the new compound has a 65 per cent pass on a modified K.I.W.A. test, and an impact strength greater than 5 ft.lb./in notch; sheet is said to have a tensile strength greater than 7,000 p.s.i. British Geon Ltd., Devonshire House, Piccadilly, London, W.1.

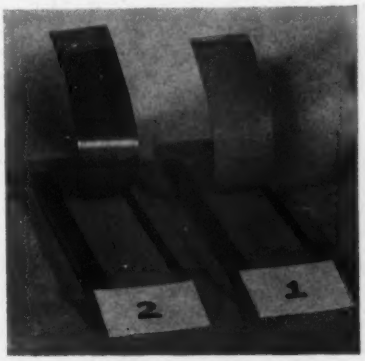
EMD 4090 for further information

Aluminium Surface Treatment

Chemlok 720 is a new type of chemical surface treatment for aluminium, and is claimed to greatly improve the adhesion of paints, lacquers, enamels, adhesives and other coatings to the metal. With all air-dried lacquers and enamels (acrylic, cellulosic, butyrate, etc.), it is said to produce adhesion unmatched by any previous treatment. With baked finishes (acrylic, vinyl, urea alkyd, melamine alkyd, epoxy alkyd, epoxies, etc.), Chemlok 720 gives improved results.

The high level of adhesion results from a chemical reaction forming polar organo-aluminium compounds of molecular thickness at the aluminium surface. This produces an organic surface which exhibits greater compatibility and adhesive strength with the organic coatings subsequently applied. The accompanying unretouched photograph of peel test results shows how Chemlok 720 surface treatment improves the adhesion of paint to aluminium. With inadequate or improper surface treatment, as in sample No. 2, the paint peels off the aluminium, leaving bare strip. After Chemlok 720 treatment (sample No. 1), the paint adheres firmly to the aluminium, and fails cohesively in the paint layer.

Chemlok 720 is also a cathodic treatment which prevents the undercutting and blistering of paint films commonly en-



countered with sacrificial anodic treatments. Retention of the paint or coating itself prevents corrosion of the underlying metal. Chemlok 720 does not affect the base colour of the aluminium, and can be used with all paints or clear coatings. The process is fast, simple, economical and produces no sludge in treatment tanks. It is adaptable to batch or continuous processing with either spray or immersion equipment. Durham Raw Materials Ltd., 1-4 Great Tower Street, London, E.C.3.

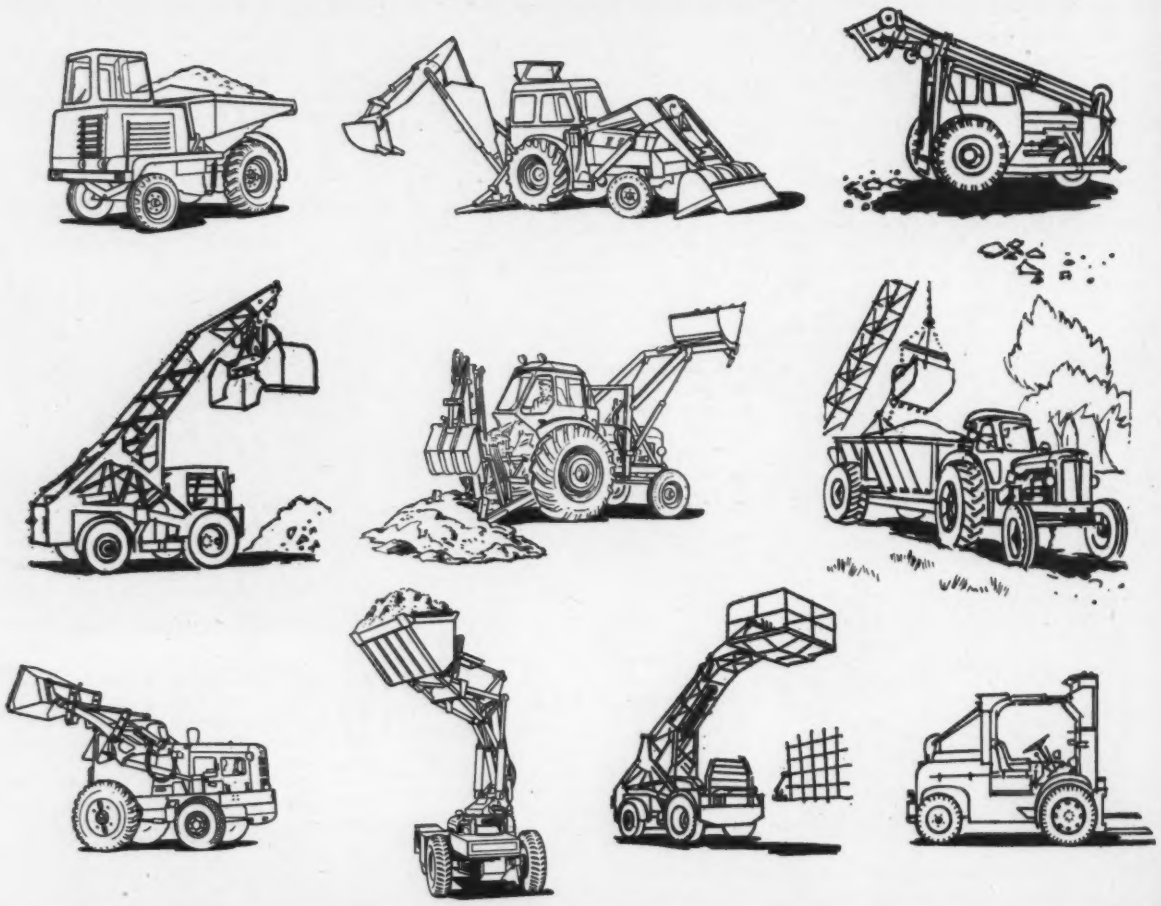
EMD 4091 for further information

Zinc-rich Primer

A zinc-rich primer known as D.M.U. F is claimed to eliminate the great deal of stirring usually necessary with this type of paint. A further advantage claimed is that the paint can be more readily used on surfaces which have not been given 100 per cent preparation, although clean, bare ferrous metal is the recommended surface. The paint can be applied by brush or roller, and its fine-grain metallic zinc (over 92 per cent) gives a satin finish which is said to be ideal for application of decorative finishes. It is said to be heat resistant up to 70 deg. C. in water, and up to 150 deg. C. dry. Detel Products Ltd., Stonefield Way, Victoria Road, South Ruislip, Middlesex.

EMD 4092 for further information

Baxenden Chemical Co. Ltd.: have pointed out that the K factor of their Clocel P.E.2. rigid polyurethane foam ("Polyurethane Foam" item on p. 649 of the October issue) is not 0·415, but the low figure of 0·145.



TOP DESIGNERS *INSIST* ON

FORDSON POWER

Britain's top designers of industrial machinery choose more Fordson power units than any other. For very good reasons too . . . proved reliability, high output at low cost in the toughest conditions, almost unlimited choice of build-ups in the 30-40 b.h.p. and 40-50 b.h.p. classes, and the backing of the Fordson world-wide service and spares organisation. And all with the low costs that come from quality volume production in the great Dagenham plant. Write for detailed specifications.

WISE BUYERS INSIST ON FORDSON POWER

INDUSTRIAL SALES DEPARTMENT TRACTOR DIVISION FORD MOTOR COMPANY LIMITED DAGENHAM ESSEX

Nuts for Projection Welding

A new range of Weldnuts has been specially developed for all types of projection welding equipment. Cold forming is claimed to ensure that the pilot and weld projections are held within close tolerances, to give consistently satisfactory welding results. The three weld projections provide a firm non-rocking electrical connection during welding, and are precisely formed to provide the exact amount of metal needed for optimum projection welds, with the minimum of current consumption. The precision pilot ring gives accurate positioning by hand or machine, and, by shrouding the lead threads, limits overheating and consequent distortion.

The Weldnuts, which are available in a variety of stock sizes, are manufactured from high-quality low-carbon cold-forming steel to BS EN 2A (28 t.s.i. minimum u.t.s.). They are supplied in self-finish, clean and free from rust or scale. Simmonds Aerocessories Ltd., Treforest, Glamorgan.

EMD 4093 for further information

Heat Dissipator

Primarily designed to form an integral part of cooling systems for mechanical shaft seals, the Crane heat dissipator is also capable of application as a heat exchanger for many other purposes. It has a capacity of 10,000 B.t.u./hr., but two or more units can be used either in series or in parallel, when the rate of flow and the required temperature drop exceed the capacity of a single unit.

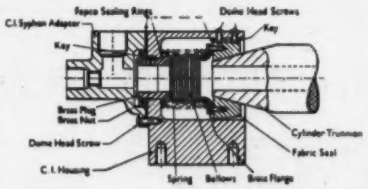
With the exception of the connections for the coolant, which are of mild steel, cadmium plated, the whole of the metal components are of stainless steel, in order that it may be proof against the attack of corrosive liquids or gases which are passed through it.

The heat dissipator is designed for pressures up to 2,000 p.s.i. for the product and 150 p.s.i. for the coolant. A chart is available to show the recommended flow rates for both product and coolant, which range between 20 and 120 gall./hr. Crane Packing Ltd., Slough, Bucks.

EMD 4094 for further information

Special-purpose Seal

The Rotocon seal has been designed for use when conveying steam, gas or liquids into rotating cylinders or drums. It is claimed to be proof against faulty alignment or leakage due to wear having taken place; the longer it is in use, the more effective it seals. The diagram shows the construction. A bellows unit is brazed at one end to a brass plug and at the other end to a brass plate. To this plate is fixed by set-screw the sealing ring. The bellows are spring-loaded so that complete sealing is ensured under conditions of varying temperature, or even in the complete absence of thermal expansion. The conical male component which bears on the



fabric seal can be made in most metals, as a separate unit to the rotating cylinder or drum. Alternatively, the cylinder shaft may be coned to provide the bearing surface. Emerson & Renwick Ltd., Peel Bank Works, Church, Accrington, Lancs.

EMD 4095 for further information

Rotary Joint

A comprehensive range of re-designed rotary joints has been developed, intended for situations where heating or cooling media are applied to rotating drums, shells or bowls. Joints can be supplied in duplex (steam feed and condensate outlets in one joint) or single type (one joint for steam feed and one for condensate outlet).

The seal or joint faces consist of a stationary Ni-resist nose casting, mounted in the port casting and sealed off by a heat-resisting rubber ring pressurised by a phosphor-bronze gland ring and robust spring, and a rotating graphite ring secured into a recess at the end of the rotating steel spindle screwed into the cylinder at the bowl end.

Standard joints operate to a maximum of 160 p.s.i.g. and a maximum of 600 r.p.m. Advantages claimed include automatic compensation for wear and expansion, attractive apearance, robust design, minimum of frictional resistance to rotation, and negligible maintenance. The rotary joints are manufactured in various specifications of stainless steel for anti-corrosive applications. Weston-Evans & Co. Ltd., Clifton, Manchester.

EMD 4096 for further information

Activated Lubricating Oil

A new type of oil specially formulated to reduce engine wear is available in S.A.E. 10W/30 or 20W/40. The oil is known as Activated Vitaflow, and is claimed to make good the major deficiency of multi-grade oils (inadequate adhesion to metals) while retaining all their other advantages. Hitherto, it is said, the benefits gained by the inherent low viscosity of multi-grade oils have been largely off-set by this lack of adhesion during periods of engine idleness.

The new oil has been treated with a special additive that is claimed to impart exceptional surface adhesion properties, thus providing an unbroken oil film at all times. A reduction in engine wear and improved performance is said to result from the provision of an adequate oil film from a cold start, and acid corrosion is eliminated. Vigzol Oil Co. Ltd., Vigzol House, Greenwich, London, S.E.10.

EMD 4097 for further information

Liquid Feeder

The Clarkson liquid feeder, now available in this country, is used for the accurate control of liquid addition in many types of process. The feeder is made from stainless steel, and is easily cleaned and sterilised. Control is by a hand wheel, and the amount fed can be varied from

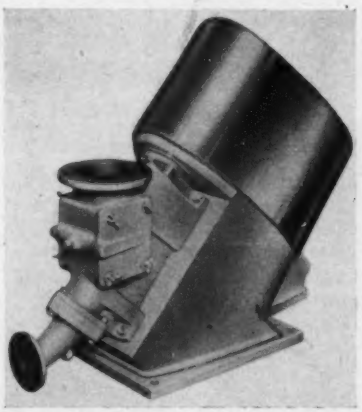
a few drops to 2 litres/min. per unit. Several units can be operated from the same gear motor, and individual control is simple. For acids and highly corrosive liquids, a feeder in p.v.c. is available. Neldco Processes Ltd., Crossway House, Bracknell, Berks.

EMD 4098 for further information

A Pump for Powders

The Mono powder pumping system is claimed to provide a compact method of piping powder for discharge at various stations, and the Junior powder pump has been developed to extend its application. The principle embodied in the pump has the effect of producing a positive and uniform rate of displacement which smoothly generates the flow of powder through pipelines.

The compact unit incorporates a driving motor and push-button starter. When used for handling powders responsive to



pumping, the rate of discharge can be varied from small amounts up to about 5 cu. ft./hr. Mono Pumps Ltd., Mono House, Sekforde Street, Clerkenwell Green, London, E.C.1.

EMD 4099 for further information

EMD 3999 for further information

THIS IS NOTHING TO WHAT GOES ON INSIDE A

BULLOWS NOPUMP

SPRAY BOOTH

ALMOST ENTIRELY ELIMINATES MAINTENANCE

NO PUMP
NO FILTERS
NO PIPES
NO NOZZLES

In this new type of Water-Wash Spray Booth the exhaust air travels at very high velocity over the water surface entraining water. The air/water mixture, moving through controlled changes of direction, provides the scrubbing action.

★ **A NEW PATENTED PROCESS OF WATER TREATMENT...** substantially increases the efficiency of these Booths.

NO CLEANING OUT AFTER 1 YEAR'S CONTINUOUS DOUBLE-SHIFT WORK AT

Massey-Ferguson
(UNITED KINGDOM) LTD.

STRETFORD · MANCHESTER

This Booth was started up on production on 1st March, 1959, and has operated two nine-hour shifts on continuous painting of agricultural machinery. When last examined, there was an average depth of silt of 6 inches over the entire water tank bottom, an area of 290 sq. feet. A further 4 inches, making 10 inches in all, can be accommodated before cleaning is essential. After 1 year's operation, the fan and ducting were barely discoloured, the only maintenance cost being cleaning the floor inside the booth, routine greasing of bearings and similar preventive maintenance.

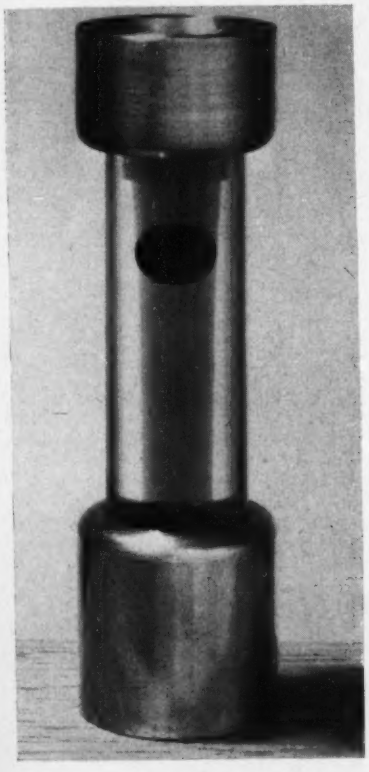
VISITS TO FACTORIES WHERE BULLOWS' NOPUMP SPRAY BOOTHS HAVE BEEN INSTALLED CAN BE ARRANGED ON REQUEST. WRITE TODAY FOR FULL DETAILS OF THIS OUTSTANDING BULLOWS' ACHIEVEMENT.

A. BULLOWS & SONS LTD · LONG ST · WALSALL · STAFFS · TEL 27251

DEPOTS AT: 13 SOUTH MOLTON ST., LONDON, W.1. TEL: MAYFAIR 2313
70 GILMOUR ST., GLASGOW, C.5 TEL: SOUTH 2383
55a BRIDGE ST., MANCHESTER, 3. TEL: BLACKFRIARS 5670
61-63 DRURY ST., DUBLIN. TEL: DUBLIN 73188/9
BULLOWS (AUST) PTY. LTD., ETHEL AVENUE, BROOKVALE, SYDNEY, AUSTRALIA

Flow Indicator for Additive Oils

The Muntz direct flow indicator has been developed for use with oils containing additives, for which in many instances the conventional type of flow indicator is useless. It consists of a ball in a transparent tube with a tapered bore, so arranged that as the flow increases the ball rises in the tube. An indication of the actual flow rate is therefore obtained. The device is at present obtainable in three different forms: (a) a standard single indicator, suitable for inclusion in any oil line; (b) a replacement indicator, which



can be substituted directly for other types of sight glasses; and (c) a multi-point panel, which is a compact arrangement designed for use where a large number of indicators is required—all the units are grouped together, and it is thus possible to check the various flows almost at a glance.

These flow indicators contain no special liquids, and it is therefore impossible to contaminate the oil. All components are said to be manufactured to close tolerances, and to be interchangeable. The various arrangements are designed to operate at pressures up to 1,000 p.s.i. Alan Muntz & Co. Ltd., Browells Lane, Feltham, Middlesex.

EMD 4100 for further information

Feeder Valves for Pneumatic Conveying

Two rotary feeder valves, specially designed to feed powdered and granular materials into pneumatic conveying lines, have been introduced.

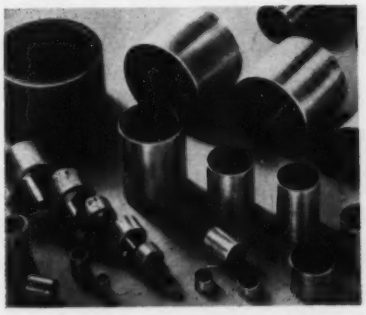
The rotary feeder type QNm has been designed to overcome problems involved in conveying fine powdered materials in high-pressure lines. It consists basically of a robust casing carrying a chain-driven multi-bladed rotor, the driving shaft being carried in roller bearings. Material fed into the pockets between the blades is discharged at the bottom of the casing, where the blow-line is connected to the inlet and outlet ports. Air contained in the empty pocket is then discharged through a neutralising port to prevent it interfering with the discharge of stock from the bin. Brass tips, inserted into slots at the periphery of each blade on the rotor, are rubber-cushioned at their base to maintain a constant seal at the point of contact with the rotor wall, and to provide automatic compensation for wear. A shear pin in the feeder drive guards against overloads or jamming.

The feeder valve PNm has been designed to achieve an uninterrupted flow of granular materials into a blowing line, while having sufficiently fine clearance to eliminate air leakage. Although based on the same fundamental principle as the type QNm feeder, the material being fed to the blowline in this case passes through the base of the valve casing to a separate suitable connection mounted below. A neutralising port is included to feed back air which would otherwise cause puffing in the bin. A self-contained motor drive is fitted, the motor and gear reduction being mounted on the side of the valve. Thomas Robinson & Son Ltd., Rochdale, Lancs.

EMD 4101 for further information

New Impregnated Bearing Range

A new range of p.t.f.e. impregnated bronze bearings for wet or dry applications, known as Polyslip 1M, has been introduced. These bearings replace a former range, and are claimed to have a performance four to five times better. In addition, by standardisation of sizes, they



are less expensive. Standard sizes are based on BS 1131, Part 5:1955, and provide internal diameters in fourteen logical steps from $\frac{1}{16}$ to $2\frac{1}{2}$ in. For each standard bore there will be, in general, two alternative lengths available.

The improved performance of Polyslip 1M dry bearings has resulted from the pores produced in the bronze sintered matrix being impregnated with a mixture of p.t.f.e. and lead additive. It is said that a PV factor of 6,500 (p.s.i. × ft./min.) will give a life of 1,000 hr. under completely dry conditions when operating with mild steel shafts at the recommended tolerances. Bound Brook Bearings Ltd., Trent Valley Trading Estate, Lichfield, Staffs. **EMD 4102** for further information

Decorative Castor

The Alwayse wheel castor, the shell portion of which is made of rigid polythene, is claimed to be lightweight, immensely strong, rustproof and silent in

operation. It is said to move smoothly in any direction, owing to the spindle being well offset from the wheel. It is intended for office equipment, trolleys, TV sets, radiograms and bookcases, and would appear to improve the appearance of the equipment to which it is fitted. The Alwayse Castor Co. Ltd., 79 Longmore Street, Birmingham, 12.

EMD 4103 for further information

Pneumatic Time-delay Relays

Pneumatic time-delay relays are devices for delaying the commencement or termination of operation of an electrical circuit relative to the energisation or de-energisation of the control circuit.

There are numerous applications for this type of unit in the sphere of electrical control, ranging from load distribution in multiple circuits which are subject to high in-rush currents, to the elimination of transient indications in temperature or level control circuits.

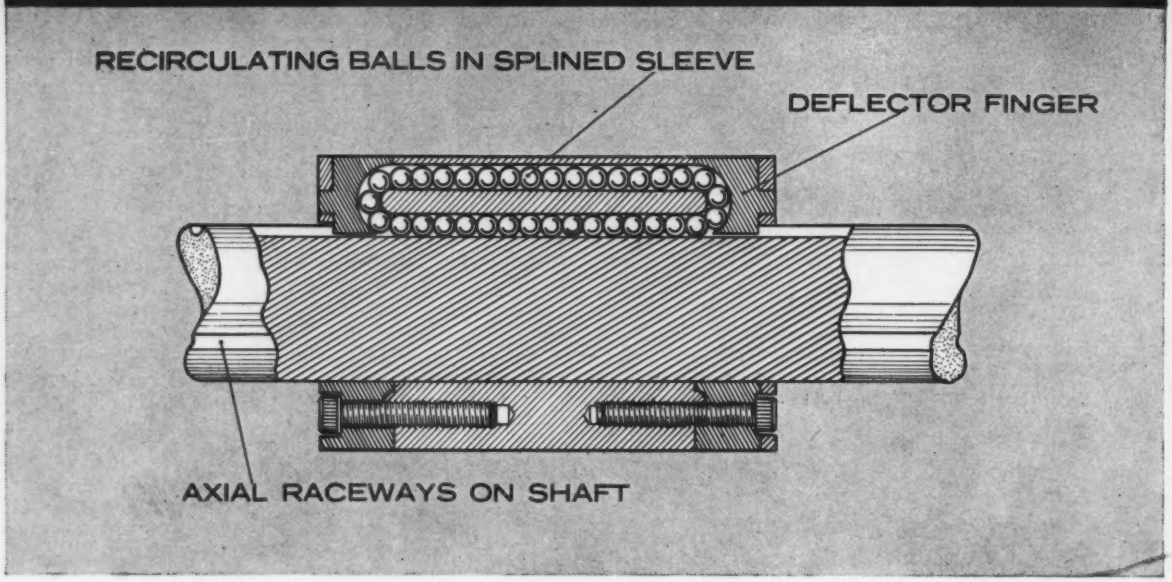
Pneumatic time-delay relays consist of a pneumatic timing unit and a solenoid mounted on a common baseplate. They can be supplied in open form or with a cast-aluminium case, and are available for either a.c. or d.c. operation. Special hermetically-sealed types are also available. Electro Methods Ltd., Caxton Way, Stevenage, Herts.

EMD 4104 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

Beaver ball splines, over 90% efficient, operate at -55°C to 450°C and over . . .



. . . ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* ball splines. These ball splines achieve a minimum efficiency of 90% and they can operate within a temperature range of −55° C to over 450° C.

Machined and ground to the highest standards of precision, Beaver ball splines are much more efficient in operation than conventional splines. They substitute a recirculating stream of precision-ground balls, rolling along specially contoured grooves, for the solid key and keyway. This arrangement reduces friction to a minimum when the spline assembly is subjected to linear, torque and bending loads. It also gives optimum smoothness and a very fine degree of positioning accuracy. When compared to conventional spline mechanisms, Beaver ball splines require a much smaller power source; provide a predictable operating life; need much less maintenance; and give long trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification and each unit is specially designed for its particular application. For Beaver splines can be made with angular pre-loading, with multiple circuits, and with telescopic extensions. Beaver splines have been proved as the most efficient method of minimising friction when high torsional and bending loads are imposed during linear movement in many engineering applications. They have been designed already with rated operating torque capacities of 50,000 lb/in (200,000 lb/in maximum static torque) but the maximum potential operating torque is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball screws
reduce the power required for actuation by as much as 80%. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion when converting rotary drive into linear output.

**Complete technical and manufacturing co-operation with Beaver Precision Products Inc, Detroit.*

For further information please write to J. B. Starky, Sales Manager, (Beaver Products Division), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED

Plastic Drawer Unit

The Victoria-minor, a seventy-two plastic-cell drawer unit, is designed for the storage of small, delicate components and scientific instruments. The body of the cabinet is made from high-grade sheet steel, subdivided by high-density hardboard forming compartments which extend right to the back of the unit. Each of its eighteen plastic drawers is completely enclosed on all sides and subdivided into four crevice-free and slightly resilient cells. At the rear of the drawer

is an extension section, so that the contents of all four cells become completely accessible when the drawer is pulled forward. The drawer fronts are moulded with a convenient handle and two inclined surfaces to carry self-adhesive labels. Unit size is 22 × 22 × 25½ in. deep. J. H. Randall & Son Ltd., Paddington Green, London, W.2.

EMD 4105 for further information

Desk Graph Plotter

This consists of a compact keyboard arrangement operating a small high-speed graph plotter with a plotting area of up to 10 × 18 in. (25 × 45 cm.). It can be used for the accurate and fast drawing of multi-channel graphs point by point. Controls are available for setting up for various sizes of graph paper, but otherwise the operator only has to key out the two numbers representing the point to be plotted on a compact keyboard having three columns of ten keys for one axis and three columns of ten keys for the other. When a key is depressed it stays down to indicate which one has been selected, but the number selected is also presented on an illuminated numerical display at the rear of the keyboard, so that it is very simple for the operator to check that the correct number has been keyed out. When the second pair of numbers is being keyed out, only the actual keys to be changed have to be operated before the print-bar is again pressed.

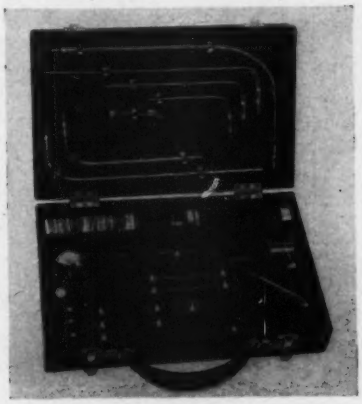
The paper is quickly fitted and held down by spring clips. Marking of the paper is by an electrically operated marker punching down through a typewriter ribbon in a manner comparable with normal typewriter operation. Carbon copies, Multilith records, etc., can be obtained in an exactly similar way to that used with a typewriter.

Such a unit would appear to have a very wide range of application for the plotting of production charts, sales curves, etc. Dobbie McInnes (Electronics) Ltd., 55 Kelvin Avenue, Glasgow, S.W.2.

EMD 4106 for further information

Industrial Inspection Kit

The Ellispection kit comprises a series of rigid and flexible probes with fixed and movable mirrors, magnifiers and midget battery-operated electric lights, the smallest being ¼ in. in diameter. All the parts are interchangeable and interlocking. Thus, one or more parts in any



combination make it possible to probe, illuminate and inspect machinery, castings, dies, pipe assemblies, chemical plants, electronic valves and many other types of plant or equipment. Insulating sleeves are also provided, for sliding over the probes when they are to be used for the inspection of electrical equipment.

This compact kit is housed in a fitted, black hardwood case which is light and easy to carry and all the metal parts are finished in durable nickel. Two standard U.2-type torch batteries, or their equivalent provide power, and are housed in the battery handle. Ellis Optical Co., Mayday Road, Thornton Heath, Surrey.

EMD 4107 for further information

New Publications and Technical Literature

The International Meehanite Metal Co. Ltd.: Leaflet of diagrams and information showing how to design Meehanite castings to cut production costs. Meerion House, 4 Downside, Epsom, Surrey.

EMD 4109

Imperial Aluminium Co. Ltd.: Catalogue (69 pages) giving full details of the Impalco aluminium alloys. P.O. Box 216, Witton, Birmingham, 6.

EMD 4110

Simmonds Aerocessories Ltd.: Well-illustrated 48-page booklet on the company's range of Nyloc and Pinnacle self-locking nuts. Treforest, Glamorgan, Wales.

EMD 4111

Hellerman Ltd.: Thirty-page illustrated catalogue of the firm's compression terminals and tools. Crawley, Sussex.

EMD 4112

Crane Packing Ltd.: Profusely illustrated 58-page catalogue and reference book on the selection and use of gland packings. Slough, Bucks.

EMD 4113

Engelhard Industries Ltd.: Leaflet of information on the firm's precious-metal thermocouples. Baker Platinum Division, 52 High Holborn, London, W.C.1.

EMD 4114

Henry Wiggin & Co. Ltd.: Eight-page brochure on Incoloy DS nickel-chromium-iron alloy (formerly known as Nimonic DS), giving details of physical and high-temperature properties, and including reference to fabrication techniques, Thames House, Millbank, London, S.W.1.

EMD 4115

Gordon & Gotch (Sellotape) Ltd.: Brochure of eleven pages on the applications and potentialities of the company's self-adhesive labels. 8-10 Paul Street, London, E.C.2.

EMD 4116

Guest Keen & Nettlefolds (Midlands) Ltd.: Leaflet of information on G.K.N. aircraft fasteners, which include high-tensile-steel, titanium-alloy and hollow-steel bolts, and high-tensile and lightweight nuts. Box 24, Heath Street, Birmingham, 18.

EMD 4117

Rubber Improvement Ltd.: Booklet of 23 pages which, while dealing specifically with Green Bond conveyor belting, is at the same time a general reference work on conveyor belting. Rilex House, Chandos Street, London, W.1.

EMD 4118

Croda Ltd.: Ten-page data sheet on Crocell, which is a non-inflammable, plastics-based, rubber-like, anti-corrosive preparation and transparent packaging material. Cowick Hall, Snaith, Goole, Yorkshire.

EMD 4119

George Angus & Co. Ltd.: Catalogue giving detailed information on the proper selection of packings and jointings; the Angus range is listed in full. 152-158 Westgate Road, Newcastle upon Tyne.

EMD 4120

Crofts (Engineers) Ltd.: Illustrated leaflet of tabulated data on Ultivee rope drives. Bradford, 3, Yorkshire.

EMD 4121

When did *you* last see a Dutch interior? Never mind! The point is that there's an art to protecting the interiors of tanks. And Ensecote has it. *Any* size of tank. *Any* sort of liquid practically. Ensecote protective linings are easily cleaned and sterilized; completely odourless, tasteless, and economical to install (larger vessels can be lined on the spot). Ensecote protective linings add years to a tank's life.

ENSECOTE *Lithcote* PLASTIC LININGS

For literature and technical advice on linings, and on tank fabrication, write to: NEWTON CHAMBERS & CO. LTD., THORNCLIFFE, SHEFFIELD, ENGLAND

Agents in Belgium, France and Holland: FOURS LECOCQ ET ATELIERS DE TRAZEGNIES REUNIS, S.A., TRAZEGNIES, BELGIUM

News of Industry

A new salt-water public swimming pool heated by solar energy has been added to the facilities of an hotel situated on the A22 London-Eastbourne road. The water is warmed by a solar energy heater invented by Mr. Harry Gatward in co-operation with **I.C.I. Metals** division. The temperature boost required is between 15 and 20 deg. F., and the solar heater operates at a very high collection efficiency and readily keeps the 50,000 gallons of water in the pool at between 65 deg. and 75 deg. F. during the summer months. The heater has been placed at ground level, and is tilted towards the south at the most advantageous angle for maximum absorption of solar energy during the period April to October. I.C.I. copper Tube-in-Strip, painted black to increase absorption efficiency and backed by insulation, is used for the collector plate. The panels are covered in front with glass plate which, while reducing incident radiation slightly, prevents re-radiation from the collector plate of energy in the infra-red region, thereby acting as a kind of radiation non-return valve and increasing collection efficiency.

In operation, the radiant energy from the sun heats the copper Tube-in-Strip panels, and the pool water (circulated by a small electric pump through the tube-ways in the material) takes up the heat energy. The cost of a unit of this type compares very favourably with alternative heating systems, while more importantly the running costs are zero since the solar energy is "free issue". I.C.I. Tube-in-Strip is being used for similar purposes in private swimming pools in the south of England, and for solar energy domestic water heaters in Malta.

One of the latest types of T.A.L. Numatics air valves has dispensed with plastics seals, and relies entirely upon stainless-steel metal-to-metal seals, each valve being individually lapped to a surface finish of 2 micro inches with a clearance of 0·00015 in. Manufactured at the works of **Austin S. Beech & Co.**, this form of sealing overcomes the difficulty of short seal life when the valve is situated in the presence of grit and dirt. The solenoid-operated valves are capable of operating up to 300 c/s per min. and are rigorously tested before dispatch.

Brush Crystal Co. Ltd., Hythe, who specialise in the development and manufacture of crystals, have formulated a method whereby strict control can be kept on the temperature of the chambers during the entire period of growth of crystals. This is said to be the only method used in any commercial undertaking in the U.K., and incorporates the use of extensive refrigeration and heating plant supplied and installed by York Shipley Ltd. Before dispatch, every Brush crystal element is subjected to rigorous inspection and test.

The inaugural committee of the **Lorry Mounted Crane Association**, formed at the end of last year, have now established the rules of membership. Because of the nature of their work, which can vary from the lifting of bank safes to the building of concrete flyovers on motorways, there can be some risk in the operation of lorry-mounted cranes unless they are handled with skill, and the work planned by experienced engineers. The Association have set out to guarantee a minimum standard of insurance, safety and reliability, and will also endeavour to rationalise legislation regarding the use of lorry-mounted cranes, which at present have to comply with a variety of regulations, including Factories Acts, Mines and Quarries Acts, building and civil engineering regulations, docks regulations, police regulations and by-laws. Other objects of the Lorry Mounted Crane Association (301 Glossop Road, Sheffield, 10) are to promote high standards in the practice of heavy lifting, and to establish a minimum set of conditions of contract.

Teleflex Products Ltd., of Basildon, have been appointed exclusive licensees for Great Britain by Shur-Lok Corp., U.S.A. Teleflex will be able to produce any and all of Shur-Lok's patented products, including their sandwich, structural and electronic fasteners, and lock-washers, some of which were shown in the survey published in *Engineering Materials and Design* of January 1959.

The **Regional College of Art**, Manchester, have recently established a Fellowship for Research in User Design, and the first Fellow, who will be in receipt of a £500 scholarship, has now been appointed and will commence work during September.

The new paint shop for the Simca motor manufacturing plant at Poissy, France, demanded a particularly involved scheme of mechanical handling, with the added complication of two production lines operating, for the greater part of the process, in parallel yet at widely differing speeds. Where the plant demanded that the two lines should knit together for a single process, the timing control for the subsequent return of the body to its appropriate conveyor line was critical. The design and installation of the complete system was carried out by **Geo. W. King Ltd**. Their design was for an automatic system which would call up bodies from the body shop a floor below, pass them through the various stages of process and inspection, deliver them to the trim line, and at the same time supply a flow of advance information to the forward lines preparing to call up bodies through each successive stage. At every point of production it was necessary to provide for last-minute changes and variations of flow.

MEETINGS AND EXHIBITIONS

Among the objectives of the **Laminated Plastic Fabricators Association**, which recently came into existence, is the intention to promote the proper application of fabricated laminated plastics and to encourage its specification by architects and builders. Exhibitions, demonstrations and meetings, both formal and informal, will be held to discuss matters of common interest, and to hear speakers on the subject of laminated plastics. Applications by bona fide laminated plastic fabricators for membership should be addressed to the Secretaries, at 11 Ironmonger Lane, London, E.C.2.

Three leading technical journals are sponsoring an educational visit to Sweden for twenty-seven-year-old post-graduate student John C. Beal, B.Sc., who is engaged on fundamental research at University College, London. The journals are *British Communications and Electronics*, *British Power Engineering* and *Nuclear Engineering*. Mr. Beal is specialising in the measurement of power, using the Hall effect in a semiconductor, both on power and microwave frequencies. During his stay in Sweden he will visit various research establishments and attend the Fifth International Instruments and Measurements Exhibition, in Stockholm, where he will also represent the sponsoring journals on the British technical publishing stand.

The technical sessions at this year's Autumn General Meeting of the **Iron and Steel Institute** will consist of two short symposia, covering "Fluid Flow in Furnaces and Converters", and "Structure, Kinetics and Properties of Martensite". The Institute is arranging a symposium on "Steels for Reactor Pressure Circuits", to be held in London from November 30 to December 2, 1960. Some twenty papers, giving the results of recent research in Canada, Great Britain and the U.S.A., are to be presented and discussed during the meeting's five sessions. These will cover high-temperature properties, corrosion, fabrication aspects, irradiation effects, and steels for future reactors, respectively.

The **British Standards Institution** have recently issued a full report on the national decisions taken at a recent conference on "Interchangeability of Shanks and Squares". This has been written by a senior member of the technical staff.

FILMS

The second in the **British Atomic News** series of films is being planned for production in October. The films are designed to show that British atomic equipment leads the world, and to promote exports. Commentaries will be made in several languages for overseas distribution by British Atomic News, 3 Albemarle Street, London, W.1.

EMD 4002 for further information

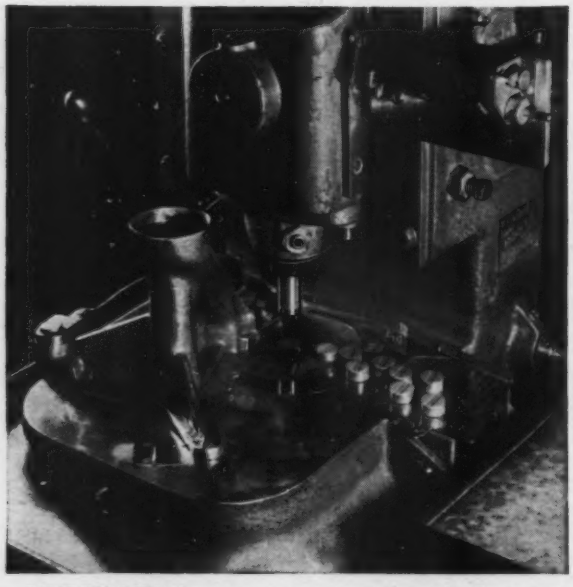
PERMANENT MAGNETS BY POWDER METALLURGY

Powder metallurgy applied to the manufacture of permanent magnets offers many distinct advantages to the designer of equipment and instruments employing magnetic circuits.

Uniformity of size and performance from one magnet to another is a major feature enabling large quantities to be produced with consistent properties throughout.

Intricate shapes to closely controlled tolerances are possible; surfaces are smooth and, generally, additional machining is unnecessary. Magnets as small as $\frac{1}{8}$" diam. x $\frac{1}{16}$" can be produced and the very nature of the process permits rapid production with low handling costs. Permanent magnets manufactured by this process are now being used on an ever increasing scale in industry. Currently they can be found in high speed generators in aircraft, moving coil instruments, kilowatt hour meters, moving coil and microcurrent relays, hearing aids, miniature microphones, synchronous motors, tachometers, thermostats and small electric motors. Alloys being produced by this process are Alcomax III, Alcomax IV, Hycomax, Alnico and Comalloy.

'Sincomax' is a development of this technique, where magnets and associated iron pole pieces are produced as composite units of high efficiency with no air gaps between magnet and pole pieces and a bond of great mechanical strength. From this originated the 'Sincomax' form of the internal magnet system. Here the magnet replaces the concentrator in the conventional moving coil system. Iron shoes become an integral part of the magnet to give an even distribution of flux.



MUREX LTD. have many years experience in the manufacture of magnets by the Powder Metallurgy technique and qualified technical staff is available to advise on magnet design and performance. Literature can be provided upon request, giving full details of our current range and information relating to design considerations.

MUREX LIMITED *(Powder Metallurgy Division)*
RAINHAM, ESSEX • *Rainham, Essex 3322*
Telex 28632 Telegrams: Murex, Rainham-Dagenham, Telex.
London Sales Office: Central House, Upper Woburn Place, W.C.1. Tel. EUSton 8265

EMD 4003 for further information

Want to dry seaweed?
or exfoliate vermiculite?
or bake bread?
or forge pitchforks?
or raise steam?
or warm people?

In thirty-two countries around the world from Iceland to New Zealand Nu-way oil burners are at work heating buildings, raising steam, melting metal, drying crops and doing hundreds of other jobs cleanly and efficiently.

NU-WAY Oil-firing

REMEMBER POPPY DAY

helps every industry
Write
NU-WAY HEATING PLANTS LTD
(BOX B313), DROITWICH
and at LONDON, MANCHESTER, NEWCASTLE, GLASGOW, BELFAST, DUBLIN, BRISTOL

Specify..
CHURCHFIELDS SPRINGS,
Pressings, Wirework, and Spring Washers

The advice of our Technical Department is at your service. Fully approved. D.A.I; A.R.B; D.I.Arm; I.E.M.E; I.N.O; I.F.V;

CHURCHFIELDS SPRING CO. LTD.
BANK ST. HALL END, WEST BROMWICH
Telegrams & Telephones STOnecross 2605 8 PBX

EMD 4004 for further information